Snake River - Hells Canyon Total Maximum Daily Load (TMDL)

Section 3.0 Loading Analyses

3.0 Loading Analyses

3.0.1 General Information

A TMDL prescribes an upper limit on discharge of a pollutant from all sources so as to assure water quality standards are met. It further allocates load capacity (LC) among the various sources of the pollutant. Pollutant sources fall into two broad classes: point sources, each of which receives a waste load allocation (WLA); and nonpoint sources, which receive a load allocation (LA). Natural background (NB), when present, is considered part of the load allocation, but is often identified separately because it represents a part of the load not subject to control. Because of uncertainties regarding quantification of loads and the relation of specific loads to attainment of water quality standards, the rules regarding TMDLs (40 CFR § 130) require a margin of safety (MOS) be a part of the TMDL.

Practically, the margin of safety is a reduction in the load capacity (LC) that is available for allocation to pollutant sources. The natural background load is also effectively a reduction in the load capacity available for allocation to human-caused pollutant sources. This can be summarized as the equation:

$$\mathbf{LC = MOS + NB + LA + WLA = TMDL}.$$

The equation is written in this order because it represents the logical order in which a loading analysis is conducted. First the loading capacity is determined. Then the loading capacity is broken down into its components: the necessary margin of safety is determined and subtracted; then natural background, if relevant, is quantified and subtracted; and then the remainder is allocated among pollutant sources. When the breakdown and allocation is completed, the TMDL must equal the loading capacity.

Another step in a loading analysis is the quantification of current pollutant loads by source. This allows the specification of load reductions as percentages from current conditions, considers equities in load reduction responsibility, and is necessary in order for pollutant trading to occur. Also a required part of the loading analysis is that the load capacity be based on critical conditions – the conditions when water quality standards are most likely to be violated. If protective under critical conditions, a TMDL will be more than protective under other conditions. Because both load capacity and pollutant source loads vary, and not necessarily in concert, determination of critical conditions can be more complicated than it may appear on the surface.

A load is fundamentally a quantity of a pollutant discharged over some period of time, and is the product of concentration and flow. Due to the diverse nature of various pollutants, and the difficulty of strictly dealing with loads, the federal rules allow for “other appropriate measures” to be used when necessary. These “other measures” must still be quantifiable, and relate to water quality standards, but they allow flexibility to deal with pollutant loading in more practical and tangible ways. The rules also recognize the particular difficulty of quantifying nonpoint loads, and allow “gross allotment” as a load allocation where available data or appropriate predictive techniques limit more accurate estimates. For certain pollutants whose effects are long term, such as sediment and nutrients, EPA allows for seasonal or annual loads.

This document represents the loading analyses for the pollutants addressed by the Snake River - Hells Canyon (SR-HC) Total Maximum Daily Load (TMDL). These include the pollutants listed in Table 3.0.1.

Table 3.0.1 Segment specific listing information for the Snake River - Hells Canyon TMDL reach

Segment	Idaho 303(d) Listed Pollutants	Oregon 303(d) Listed Pollutants
Snake River: RM 409 to 396.4 Upstream Snake River (OR/ID border to Boise River Inflow)	(downstream from ID border) bacteria, dissolved oxygen, nutrients, pH, sediment	mercury, temperature
Snake River: RM 396.4 to 351.6 Upstream Snake River (Boise River Inflow to Weiser River Inflow)	bacteria, nutrients, pH, sediment	mercury, temperature
Snake River: RM 351.6 to 347 Upstream Snake River (Weiser River Inflow to Scott Creek Inflow)	bacteria, nutrients, pH, sediment	mercury, temperature
Snake River: RM 347 to 285 Brownlee Reservoir (Scott Creek to Brownlee Dam)	dissolved oxygen, mercury, nutrients, pH, sediment	mercury, temperature
Snake River: RM 285 to 272.5 Oxbow Reservoir	nutrients, sediment, pesticides	mercury, temperature
Snake River: RM 272.5 to 247 Hells Canyon Reservoir	not listed	mercury, temperature
Snake River: RM 247 to 188 Downstream Snake River (Hells Canyon Dam to Salmon River Inflow)	temperature	mercury, temperature

Because of the extensive scope of this TMDL, the SR-HC TMDL process has divided the SR-HC reach into five separate segments based on similar hydrology, pollutant delivery and processing mechanisms, and operational, management or implementation strategies. The five segments are:

- The Upstream Snake River segment (RM 409 to 335)
- The Brownlee Reservoir segment (RM 335 to 285)
- The Oxbow Reservoir segment (RM 285 below Brownlee Dam to RM 272.5)
- The Hells Canyon Reservoir segment (RM 272.5 below Oxbow Dam to RM 247)
- The Downstream Snake River Segment (RM 247 below Hells Canyon Dam to RM 188)

Pollutant sources within the SR-HC TMDL reach include point sources, nonpoint sources and tributary inflows. These sources will each be discussed in the context of the segment to which they discharge.

Permitted point sources are listed in Table 2.5.0. This category includes those sources that discharge from a discrete point under the requirements of a discharge permit. For the SR-HC TMDL reach there are 9 permitted point sources, some of which have multiple discharges. For example, until recently IPCo had cooling water, sump water, and wastewater discharges associated with the Oxbow Dam and hydropower facility. The majority of the facilities in Table 2.5.0 are wastewater treatment facilities and industries with wastewater, process water, cooling water and permitted stormwater discharges.

Nonpoint sources are generally those sources that discharge over a diffuse area. They are generally not permitted and are more difficult to quantify than point sources due to the disperse nature of their discharges. Nonpoint source discharge occurs in all segments of the SR-HC TMDL reach and includes agriculture, forestry, urban/suburban, stormwater, groundwater and natural loading.

Tributary inflows to the SR-HC TMDL reach include the mainstem Snake River upstream of RM 409, the Owyhee, Boise, Malheur, Payette and Weiser rivers and numerous small streams. For the purposes of this TMDL, the tributary inflows have been treated as discrete nonpoint sources. Although it is recognized that pollutant loads to the tributaries stem from a variety of point and nonpoint sources within the tributary drainage, the mixed loading that reaches the Snake River is considered to be nonpoint source in nature.

A general discussion of methods available for the determination of pollutant loading, and a general water balance determination and hydrology assessment is available in Appendix G.

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3.1 Mercury Loading Analysis

Due to the fact that essentially no water column data are available to this effort, a TMDL cannot be established for mercury for the SR-HC TMDL reach. Therefore, IDEQ and ODEQ have determined it is in the public interest to reschedule the mercury TMDL for the SR-HC TMDL reach. IDEQ will reschedule the mercury TMDL to 2006 in order to gather additional data to better determine the sources and extent of mercury contamination. ODEQ's schedule for the mercury TMDL coincides with this date.

The state of Oregon is developing capability to model site-specific bioaccumulation factors. Also, Oregon's mercury TMDL is not due until 2006. This schedule change will allow a better use of these capabilities and the opportunity to collect additional data.

Both Idaho and Oregon have interim measures in place to deal with mercury contamination such as sediment controls and fish consumption advisories as described in Section 3.1. It is the opinion of the DEQs that this schedule change will not present an adverse impact to the SR-HC TMDL reach.

The discussion of mercury loading presented below is a preliminary assessment only. This assessment will be augmented with additional data and evaluation tools as monitoring and modeling efforts progress. A final loading analysis and load allocation will be completed by December 2006. The final assessment will replace the preliminary assessment presented below.

3.1.1 Water Quality Targets and Guidelines: Current and Pending

The purpose of TMDL development is to meet applicable water quality standards. As a bi-state TMDL addressing interstate waters, the applicable targets for this effort have been identified as the most stringent of each state's water quality standards. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met. The water quality standards and guidance values appropriate to mercury in the SR-HC TMDL are discussed below.

3.1.1.1 FEDERAL.

The US Food and Drug Administration (US FDA) has established a criterion of 1 part-per-million (mg/kg) methylmercury in fish tissue (US FDA, 1984) as an action level to protect against potential health risks for human consumption of fish. Recently (US FDA, 9 March 2001), the US FDA also announced an advisory on methylmercury in fish, specifically recommending that pregnant women, women of childbearing age who may become pregnant, nursing mothers and young children not eat certain types of ocean fish that may contain high levels of methylmercury.

Mercury criteria promulgated by the US EPA identify a water column concentration of 0.051 ug/L as a maximum for waters where fish are being harvested for human consumption, and a water column concentration of 0.050 ug/L, for waters where fish harvest occurs in combination with water being used as a domestic water supply (Federal Register 63, No 237, 68357, 1998). In response to further study and assessment nationwide, the US EPA has recently released new guidance under section 304(a) of the Clean Water Act (US EPA, 2001a) that identifies a criterion for methylmercury in fish tissue of 0.3 parts-per-million (mg/kg) to protect the health of consumers. This criterion has been developed to address the consumption of larger fish portions (17.5 grams as opposed to 6.5 grams previously) by the general public. The US EPA expects this criterion to be used as guidance by states when in establishing or updating water quality standards and fish consumption advisories.

3.1.1.2 STATE OF OREGON.

The State of Oregon has adopted an action level of 0.35 parts-per-million (mg/kg) for methylmercury in fish tissue for Oregon waters. This level is used as a screening factor in determining the need for establishing fish consumption advisories to protect human health. The State of Oregon has also adopted a water column criterion of 0.144 ug/L for methylmercury (OAR 340-41-725, 765, 805, 845 (2) (p)(B) which references an earlier version of EPA Table 20).

3.1.1.3 STATE OF IDAHO.

The State of Idaho has adopted an action level of 0.5 parts-per-million (mg/kg) for methylmercury in fish tissue for Idaho waters. This level is used as a screening factor in determining the need for establishing fish consumption advisories for the protection of human health. The State of Idaho has also adopted a water column criterion of 0.012 ug/L for methylmercury based on extrapolation of the US FDA target of 1.0 parts-per-million (mg/kg) methylmercury in fish tissue using a US EPA report documenting the use of bioconcentration factors for the determination of water column criteria (US EPA, 1984). In response to recent advances in analytical technology and better understanding of methylmercury transport and uptake in living systems, the State of Idaho action level for methylmercury in fish tissue, and the associated guidelines for issuing fish consumption advisories are currently undergoing review. New action levels and guidelines are expected to be identified late in 2003 (personal communication, M. Wen, IDHW-EHS, May 2001).

The most stringent applicable water quality standards for mercury in the SR-HC TMDL area are the 0.012 ug/L water column methylmercury adopted by the State of Idaho, and the 0.35 parts-per-million (mg/kg) fish tissue concentration criteria established by the State of Oregon. These represent preliminary targets for mercury for the SR-HC TMDL. The final TMDL, to be completed in 2006, will identify final targets for mercury in the SR-HC TMDL reach.

3.1.2 Designated Beneficial Use Impairment

The SR-HC reach is listed from RM 409 to RM 188 for mercury. To date, data available show that mercury concentrations in the SR-HC reach of the Snake River exceed the fish tissue target established by this TMDL. Water column data is not available to allow an assessment of the use support status of aquatic life uses due to mercury concentrations within the SR-HC system.

All fish tissue data available in this reach were positive for mercury. A summary of these data show that the Oregon and Idaho levels of concern were exceeded by 80% (0.35 mg/kg) and 52% (0.5 mg/kg) respectively. Both states have acted to issue fish consumption advisories based on these exceedences. The US FDA action level for fish tissue (1.0 mg/kg) was exceeded in less than 10% of the fish tissue samples taken from the Upstream Snake River segment, and less than

3% of the fish tissue samples taken from the Brownlee Reservoir segment. The very limited data set available show no (0%) measured exceedences of the 0.050 ug/L US EPA water column criteria, however, detection limits were above this value by almost an order of magnitude in most cases.

The two samples in the Upstream Snake River segment exceeding the US FDA criteria occurred in channel catfish collected from the Snake River near the mouth of the Owyhee River and near Nyssa, Oregon. The three samples exceeding the US FDA criteria in Brownlee Reservoir occurred in channel catfish, crappie and smallmouth bass collected from Brownlee Reservoir near the mouth of the Burnt River.

Although there are no data available that show direct impairment of aquatic life uses due to mercury concentrations within the SR-HC system, the designated beneficial use of fishing is not fully supported due to fish consumption advisories for methylmercury established by the states of Oregon and Idaho. Therefore, the 303(d) listing of non-support is based on the presence of fish consumption advisories rather than the violation of water quality standards for mercury. Because of this, an appropriate initial target by which to evaluate the support status of the designated fishing use is the fish tissue target of 0.35 parts-per-million (mg/kg) identified by the SR-HC TMDL. There is insufficient data to determine the use support for aquatic life uses or for the wildlife and hunting use designation.

3.1.3 Mercury in Surface Waters

Mercury is a naturally occurring element, present in the environment in three principal forms: elemental, inorganic and methylated (or organic) mercury. Geologic deposits of mercury occur naturally in an inorganic form as the mineral cinnabar (HgS) in several areas of the SR-HC watershed, mainly the Owyhee and Weiser River drainages (Koerber, 1995; Gebhards *et al.*, 1971).

Air deposition and sediment transport and deposition processes (erosion) can result in mercury entering surface water systems. Once in the water, mercury can be converted from one form to another. Particle-bound mercury can be concentrated in areas of sediment deposition through particle settling, and then later released by diffusion or re-suspension. Much of the inorganic mercury entering surface water systems attaches to particles and sinks to the bottom. While inorganic or sediment-bound mercury can be absorbed by aquatic organisms, the rate and efficiency of the uptake is much lower than that for methylated or organic mercury. Inorganic forms of mercury can be converted to organic forms by microbial action. In an organic form (commonly methylmercury), mercury can easily enter the food chain, or it can be released back to the atmosphere by volatilization (USGS, 1995). Many factors influence the form, concentration and transport of mercury in the environment, these include the concentration of dissolved organic carbon (DOC), the pH of the water system, and the concentration of dissolved oxygen in the water (Hurley, 2001).

In aquatic systems, the majority of mercury binds to organic matter and fine particulates, the transport of mercury bound to larger, bed-sediment particles in rivers and lakes is generally less substantial than that observed for smaller, finer sediment fractions (US EPA, 2001a and 2001e).

Particulate-bound mercury has been shown to move through the food chain through ingestion by filter feeding organisms and through conversion to dissolved forms. Mercury-bound particle sizes range from colloidal materials (diameters less than a micron) to particles with diameters of tens of microns (MASCO, 2001).

In the bottom sediments, the most important conversion is the bacterially mediated methylation of mercury involving the addition of methyl groups to the mercuric ion (Hg^{2+}) by means of enzymatic activity (Agostino, 2001; MASCO, 2001; NWF, 2001). This conversion of inorganic to organic mercury occurs at different rates in different waterbodies. That is why some waterbodies with high levels of total mercury, but low rates of conversion to methylmercury, may not carry fish advisories while others do.

The exact mechanism(s) by which mercury is converted to methylmercury and readily enters the food chain remain largely unknown, and probably vary among ecosystems. It is known however, that certain bacteria play an important initial role. Many anaerobic bacteria, living at the sediment/water interface, including many strains of *Staphylococci*, *Streptococci*, yeasts and *Escherichia coli* (present in human intestines), are able to convert inorganic or elemental mercury into methylmercury (Ely, 1970; MASCO, 2001; NWF, 2001).

Studies have shown that bacteria that process sulfate (SO_4^{2-}) in the environment take up mercury in its inorganic form, and through metabolic processes convert it to methylmercury. According to current understanding, some of the “right” ingredients for producing methylmercury are found in systems that are rich in carbon, and low in dissolved oxygen (Hurley, 2001). The conversion of inorganic mercury to methylmercury is important for two reasons: (1) methylmercury is much more toxic than inorganic mercury, and (2) organisms require considerably longer to eliminate methylmercury (USGS, 1995). Methylmercury has low aqueous solubility and tends to accumulate in the lipid-rich tissues of aquatic organisms.

While most people and wildlife can generally tolerate extremely low levels of mercury. When mercury enters the body it becomes concentrated in tissue, an effect known as bioaccumulation. Since this element is toxic at very low concentrations, even slight increases in the minute concentrations naturally present in the environment can have serious effects on humans and wildlife (NWF, 1997).

Methylmercury is absorbed by tiny aquatic organisms such as phytoplankton and then zooplankton, which are in turn eaten by small fish. The chemical is stored in the fish tissue and is passed on at increasing concentrations to larger predator fish. People and wildlife at the top of the food chain are consequently exposed to elevated amounts of methylmercury through the contaminated fish they consume (NWF, 1997). Additionally, methylmercury is not eliminated effectively by metabolic systems and will continue to accumulate in fish as they age (Allen-Gil *et al.*, 1995; Allen and Curtis, 1991; Benson *et al.* 1976), creating the greatest risk for bioaccumulation in older, predatory fish species (Agostino, 2001). Bioconcentration factors of 63,000 for freshwater fish, 10,000 for salt-water fish, 100,000 for marine invertebrates, and 1,000 for freshwater and marine plants have been observed (US EPA, 2001b).

Studies have shown that for the same species of fish taken from the same region, increasing the acidity of the water (decreasing pH) and/or the dissolved organic carbon content generally results in higher body burdens in fish, possibly because lower pH increases ventilation rate and membrane permeability, accelerates the rates of methylation and uptake, affects partitioning between sediment and water, or reduces growth or reproduction of fish (US EPA, 2001e; USGS, 1995). However, many of the details of the aquatic mercury cycle are still unknown, and remain areas of active research.

While many factors are known to influence the accumulation of mercury in aquatic organisms (pH, water temperature, the amount of dissolved organic material present, etc.), how these factors relate to each other and to the bioaccumulation of methylmercury is still poorly understood. No single factor has been generally correlated with level of mercury accumulation in aquatic organisms. Therefore, even though two water bodies may be very similar in physical characteristics, the measured concentrations of methylmercury in fish may be very different between the two (US EPA Mercury Web Site and 2001b).

In addition, the transformation of inorganic mercury to methylmercury is not well defined. It is currently linked to both chemical and microbial processes and often occurs in a cyclic fashion within surface water systems. Thus, inorganic mercury in a surface water system represents a potential source of methylmercury if appropriate conditions exist (US EPA Mercury Web Site and 2001b).

The evaluation of mercury within aquatic systems is still an evolving science. Analytical methods have improved dramatically over the last few years as evidenced by increased accuracy and lower detection limits, and state and federal policy and guidance have undergone many changes.

3.1.4 Sources

Both natural and anthropogenic sources of mercury are known to occur in the SR-HC TMDL drainage. External sources of mercury loading to this reach include natural and background loads from the watershed and air deposition from point and nonpoint sources.

3.1.4.1 NATURAL GEOLOGICAL SOURCES.

Natural sources of mercury include volcanic rocks and mineral deposits in the rocks and soils in several areas of the SR-HC drainage. Cinnabar, the most commonly occurring ore of mercury, contains 86.2% mercury and can occur as impregnations and vein fillings in near-surface environments from solutions associated with volcanic activity and hot springs. Cinnabar can also occur as placer type concentrations produced with the erosion of mercury-bearing rocks (ADEQ, 1999a and 1999b). Natural weathering and erosive processes can increase the transport and mobility of the mercury associated with these deposits. Concentrations of mercury identified in various rocks and soils are shown in Table 3.1.1.

Mercury concentrations identified in the Owyhee River drainage are notably higher than those identified in other areas. Some of these deposits contain enough mercury that they have been mined profitably. These deposits represent potential sources of natural loading to the SR-HC reach. Additionally, given the high level of geothermal activity in the Owyhee River drainage, natural, geothermal releases may also be a significant and persistent source of mercury in the

Table 3.1.1. Identified concentrations of mercury in different rock and soil types.

Type or location	Mercury (ppm)	Reference
Igneous rocks (international)	0.01 to 0.1	Fleischer *et al.*, 1970; ATSDR, 1994a
Sedimentary rocks	0.01 to 0.05	ATSDR, 1994a
Owyhee River Basin rocks	<0.1 to 6.2	Koerber, 1995
Background rocks	0.01 to 0.05	Andersson, 1979
Western soils	0.5	Hill, 1973
Average of all soils	0.02 to 0.625	ATSDR, 1994a
SE Oregon and N Nevada soils	0.032 to 0.051	Schacklette and Boerngen, 1984
Owyhee River Basin soils	0.1 to 565.0	Koerber, 1995

area (Allen and Curtis, 1991). Mercury deposits have also been identified in the Weiser River drainage (IDEQ, 1985), although mining activities in this drainage were more limited in scope.

Anthropogenic sources of mercury in the SR-HC area include historic use of fungicides and seed treatments in the Snake River Basin, sewage sludge and compost, landfills and industrial processes, legacy mining activities, current mining activities, air deposition from sources both inside and outside the area, cement plants and coal-fired power plants. Tributary flows to the Snake River also potentially deliver mercury from both natural and anthropogenic sources within tributary drainage areas.

3.1.4.2 SEED TREATMENTS.

From the 1950's to the 1980's, chemical treatments containing mercury were used on seed grains in the US. During 1970, mercurial seed treatment on winter and spring wheat in Idaho was estimated to be equivalent to 720 pounds (327 kg) of mercury annually (Gebhards *et al.*, 1971). The use of these seed treatments was discontinued in the 1980's. Historically, the mercury in these treatments may have contributed to water contamination due to field drainage and irrigation water return in some areas. While the use of these treatments has primarily been discontinued in the US, residual mercury in agricultural soils may still be contributing a small amount of mercury to the SR-HC system through sediment transport and erosion.

Assuming the usage estimated for 1970 is representative of the average usage during the time that seed grains treated with these compounds were used in Idaho, a total of 25,200 pounds (11,454 kgs) of mercury would have been applied in the form of seed treatments in Idaho. The majority of the upstream drainage for the SR-HC TMDL is contained in the state of Idaho. Approximately 67% of the total grain grown in Idaho in 1970 was produced in the Snake River Basin upstream of Hells Canyon Dam (USDA-NASS, 2001). Assuming that the 1970 distribution of agricultural land devoted to grain production throughout the state is representative of the distribution during the time when mercury-containing seed treatments were used (roughly 1950 to 1985), 67% of the total mercury from seed treatments (16,884 pounds, 7,675 kgs) would have been applied in the Snake River Basin. In Oregon, assuming that use of seed treatments in the southeastern portion of the state was similar to that in Idaho, 1,077 pounds of mercury (489 kgs) in the form of seed treatments was applied during this same 35-year period. Total mercury from usage of seed treatments in the drainage above Hells Canyon Dam is estimated at 17,961 pounds (8,164 kgs) over the 35 year time period (513 pounds/year, 233 kgs/year).

While a percentage of this total could leach, over time, to the Snake River system and be transported downstream, treated seed grains were planted over a very large area (roughly 642,000 acres). Assuming that all acres were planted with the same density of seed, the calculated mercury loading is 0.013 kg per acre. Not all land on which mercury-treated seeds were planted is still in agricultural use, however, irrigation and cropping practices on current agricultural lands are much improved from those used previously. Flood and furrow irrigation has been replaced in many areas with sprinkler or drip irrigation systems that result in substantially lower erosion and sediment transport. Management techniques currently in use such as straw mulching and PAM application have also been reported to reduce sediment transport. With reduced erosion and sediment transport probability, and the cessation of use in the mid 1980's, the mercury from legacy seed treatments in the Snake River Basin is not identified as a substantial source of current mercury loading to the SR-HC reach.

3.1.4.3 Sewage Sludge (or Biosolids) and Wastewater Treatment Plants.

Mercury concentrations in domestic wastewater sludge range from 0 to 2.2 mg/L. The average concentration defined by the US EPA is 0.28 mg/L (US EPA, 1984b). The application of sewage sludge to croplands can result in increased levels of mercury in soil. However, land application operations are permitted activities and are generally monitored for heavy metals accumulation in soils. They are also sited and managed such that the risk of discharge of either runoff water or eroded materials into surface water systems is low. Under general circumstances, therefore, these facilities are not identified as a substantial source of mercury loading to the SR-HC system.

Wastewater treatment plants have been observed to discharge elevated concentrations of mercury due to the waste from dental offices and medical waste disposal. Four wastewater treatment plants currently discharge to the Snake River in the SR-HC TMDL reach. Industrial discharges can also carry substantial concentrations of mercury depending on what is being manufactured. Battery and florescent light-bulb manufacturers have been documented to elevate mercury levels in their waste-streams. No such manufacturing facilities discharge directly to the Snake River within the SR-HC TMDL reach.

No mercury monitoring is currently available to determine the loading to the SR-HC TMDL reach that these sources represent.

3.1.4.4 Landfills.

A number of landfills are sited in the SR-HC drainage basin. The US EPA has identified the greatest source of mercury loading in landfills to be associated with the disposal of batteries (the primary source), and other items such as broken florescent bulbs and thermometers. However, due to their relative sparseness and general locations in the area (away from surface and ground water influences), these facilities are not identified as a substantial source of mercury loading to the SR-HC system.

3.1.4.5 MINING.

Gold, silver and mercury mining has occurred historically in the SR-HC drainage area between 1860 and 1920, primarily in the area of the Owyhee River watershed. Mercury ore (cinnabar) deposits have been identified in the Owyhee and Weiser drainages (Koerber, 1995; Gebhards *et al.*, 1971). Transport and deposition of mercury from these sources may contribute to the soil and water concentrations within the SR-HC drainage area (Koerber, 1995). The Weiser River drainage also experienced mining in the early to mid 1900's. The Idaho-Almmaden mine located about 11 miles east of the City of Weiser, produced over 600 tons of liquid mercury in a process where ore is roasted and then mercury vapors are condensed and collected. The mine operated between 1939 and 1942 (152 tons), then reopened and operated between 1955 and 1961 (456 tons) (Alt and Hyndman, 1989).

Mercury was used historically in the extraction process to remove gold from raw ore. Before the beginning of the 20th century, mercury amalgamation of gold ores was a common practice throughout the Western US (Hill, 1973; Allen-Gil *et al.*, 1995; Allen and Curtis, 1991; ADEQ, 1999a and 1999b). Most of the mercury in the amalgam was recovered, but some washed out with the fines. Amalgam furnaces may also have resulted in soil contamination through short-range deposition (ADEQ, 1999a and 1999b). Mercury in mine tailings is commonly in the elemental form. However, stream sediments in the area of tailings piles are often enriched in elemental and exchangeable forms of mercury (ADEQ, 1999a and 1999b). Observed mercury concentrations in legacy gold and silver tailing piles can range up to 5 mg/kg at various sites throughout North America (Lacerda, *1990*; Allen-Gil *et al.*, 1995; Allen and Curtis, 1991). Additionally, while gold and silver mining do not directly increase the availability of mercury within the watershed, rock-crushing activities associated with the extraction process that reduce the particle size of mercury-containing rock and increase the amount of mercury available in a readily erodable form (ADEQ, 1999a and 1999b).

A study conducted jointly by IDHW and IDFG in 1970 showed that bottom fish collected from areas in the Snake River Basin with substantial legacy mining activities exhibited mercury concentrations in muscle tissue that averaged 0.520 mg/kg. Rainbow trout in the same area averaged muscle tissue mercury concentrations of 0.231 mg/kg. Bottom fish and rainbow trout from an area outside the influence of mining activities averaged muscle tissue mercury concentrations of 0.275 mg/kg and 0.102 mg/kg respectively. While the date of this study indicates that the analytical technology used is not as robust and accurate as that available today, a relative comparison of values remains valid. The data indicate that the levels of mercury in fish tissue in fish exposed to mining wastes is nearly double that of fish in the same geologic area (e.g. exposed to natural sources of mercury) but not exposed to mining wastes (Gebhards *et al.*, 1971).

The Owyhee River flows into the Snake River in the Upstream Snake River segment of the SR-HC TMDL at RM 396.7. Mercury concentrations in bed sediments of Owyhee Reservoir average 1.4 ug/g, with most of the mercury (92%) being associated with sediment particles greater than 1 mm in diameter. Water column mercury measured in the Owyhee Reservoir averaged 0.37 ug/L (range 0.07 to 0.67 ug/L) (Allen-Gil et al., 1995; Allen and Curtis, 1991). Given the 715,000 acre-foot volume of the reservoir, this represents a total mass of 327 kg of mercury in a dissolved and therefore fairly mobile form. The mean mercury concentration in sediment reported for Owyhee Reservoir was higher than that reported for numerous other lakes in the Northwest (Allen-Gil et al., 1995; Allen and Curtis, 1991).

Mercury loading in Owyhee Reservoir is most likely derived from natural deposits exacerbated by legacy mercury, gold and silver mining in the area. It is estimated that more than 76 pounds of mercury were lost daily during mining years in Idaho (Hill, 1973; Allen-Gil *et al.*, 1995; Allen and Curtis, 1991). The Idaho Historical Society reported that one mill in the Owyhee River drainage (Silver City) "lost" 2.5 tons of mercury between 1866 and 1888. Free mercury was visible in the soil and rock crevices at a mill site in the same area as late as 1971 (Gebhards *et al.*, 1971).

Mercury concentrations in sediments from the Weiser River were also evaluated (Buhler *et al.*, 1984). The mean sediment mercury concentration in the mainstem Weiser River was 0.054 mg/kg (dry weight). The mean sediment mercury concentration in tributaries to the Weiser River was 1.30 mg/kg (dry weight).

Little information is available to determine the mercury loading to the Snake River from the Owyhee River drainage or from any of the other tributaries to the Snake River in the SR-HC reach. One of the major problems encountered is the lack of water column data. The majority of water column data available was collected prior to 1990 and is therefore not easily correlated with current analytical technology. In addition, this data, and that collected in the 1990's show no measurable concentrations above the detection limits. The elevated concentrations of mercury in the soils and water of the Owyhee River drainage indicate that it represents a substantial source of potential loading from both natural and anthropogenic sources. Anthropogenic loading is assumed to be primarily the result of legacy mining activities.

3.1.4.6 AIR DEPOSITION.

Air deposition of mercury has recently been identified as a substantial source of mercury loading in the US (US EPA, 1997a and 1997b). The anthropogenic air deposition rate for the SR-HC reach estimated by this report is 1 to 3 $ug/m^2/yr$ (US EPA, 1997a and 1997b). Using a mean value of 2 $ug/m^2/yr$, this yields a potential deposition of 13 kg/year of mercury to the land area directly discharging to the SR-HC TMDL reach and 380 kg/year of mercury to the land area in the Snake River drainage area above Hells Canyon Dam. The primary source of atmospheric mercury identified by this report is the combustion of fossil fuels. Current emissions of mercury from manufacturing sources are low compared to combustion sources, with the exception of chlor-alkali plants and portland cement manufacturing plants.

Recent guidance on mercury deposition released by US EPA in 2001 report a "typical low level air deposition load" as 10 ug/m^2. A study of the San Francisco area measuring wet and dry deposition rates for the San Francisco estuary at 4.2 $ug/m^2/year$ and 19 $ug/m^2/year$, respectively (Tsai, 2001). Adjustment of the original calculated loading from air deposition to reflect the updated UP EPA deposition loads increases the original estimate to a potential deposition of 65 kg/year of mercury to the land area directly discharging to the SR-HC TMDL reach and 1,900 kg/year of mercury to the land area in the Snake River drainage area above Hells Canyon Dam.

Even without site-specific data, assuming that actual deposition loads are bracketed by these two estimates gives a strong indication that air deposition represents a substantial source of mercury loading to the SR-HC TMDL reach.

3.1.4.7 Portland-Process Cement Plants.

There is currently one operating cement plant in the immediate SR-HC drainage, the Ash Grove plant at Durkee, OR. Monitoring indicates that this plant produces emissions containing approximately 109 pounds (49.5 kg) of mercury per year.

3.1.4.8 Coal-Fired Power Plants.

There is only one coal-fired power plant operating in the Snake River region. The power plant at Boardman, OR is located in the Willow Creek subbasin in Oregon, near the Oregon/Washington border, approximately 100 miles northwest of the northern extent of the SR-HC TMDL reach. This plant produces emissions containing approximately 186 pounds (84.5 kg) of mercury per year when operating at full capacity.

The prevailing wind direction in the SR-HC watershed is from west to east. As both of these facilities are located west of the SR-HC area, there is a potential for at least some of the mercury loading from these plants to reach the SR-HC TMDL drainage. Probability is higher that the Ash Grove cement plant will be a greater contributor however as it is located nearly due west of the SR-HC reach while the Boardman plant is located to the northwest of the SR-HC TMDL area. Mercury emitted from these types of sources can travel for long distances depending on the chemical form it is in and the climate. Areas of relatively low precipitation offer less chance for the mercury to be deposited close to the source, as wet deposition will not occur regularly. Dry deposition, where mercury adsorbs to suspended particles usually results in longer-range transport than wet-deposition where mercury is captured in rain or snow and falls down with the drops. Dry deposition is expected to be the most common form of air deposition for mercury in the SR-HC reach.

3.1.5 Transport and Delivery

Sediment transport of mercury is expected to be highest in drainages where steep slopes, relatively sparse vegetation and precipitation occurring primarily in the form of snowfall combine. Sparse vegetation and timing of snowmelt in the Owyhee and Weiser River drainage, and in much of the rest of the SR-HC drainage where geologic deposits of mercury occur, produce conditions favoring high surface runoff and sediment transport.

Flooding can also enhance mercury transport and bioaccumulation. Flooding results in a surge of mercury and other materials into local reservoirs where methylation occurring in flooded shorelines and near shore sediments may result in higher rates of bioaccumulation. This mechanism has been documented (Phillips *et al.*, 1987) in the Upper Missouri River Basin where northern pike were observed to exhibit higher mercury concentrations in the year following significant flooding than in previous or succeeding years.

Additionally, land use patterns may play a role in determining the behavior of mercury in reservoir systems (Allen-Gil *et al.*, 1995; Allen and Curtis, 1991; Sorensen *et al.* 1990). Land use patterns may act to influence mercury transport within a drainage area to surface water systems and within reservoir systems. Unfortunately, the relative impact of land use practices is not quantifiable with the available data for the SR-HC system.

A report prepared by CH2MHill for IPCo (IPCo, 2000d) identified sediment mercury levels and associated particle sizes within the SR-HC reach. As discussed in more detail in Section 3.1.6, the samples containing the greatest concentrations of mercury in the Upstream Snake River segment (RM 409 to 335) contained larger-size sediment particles, suggesting that the mercury is present in either its native form or as cinnabar (HgS) (IPCo, 2000d) and is most likely deposited in this stretch through erosion and transport processes.

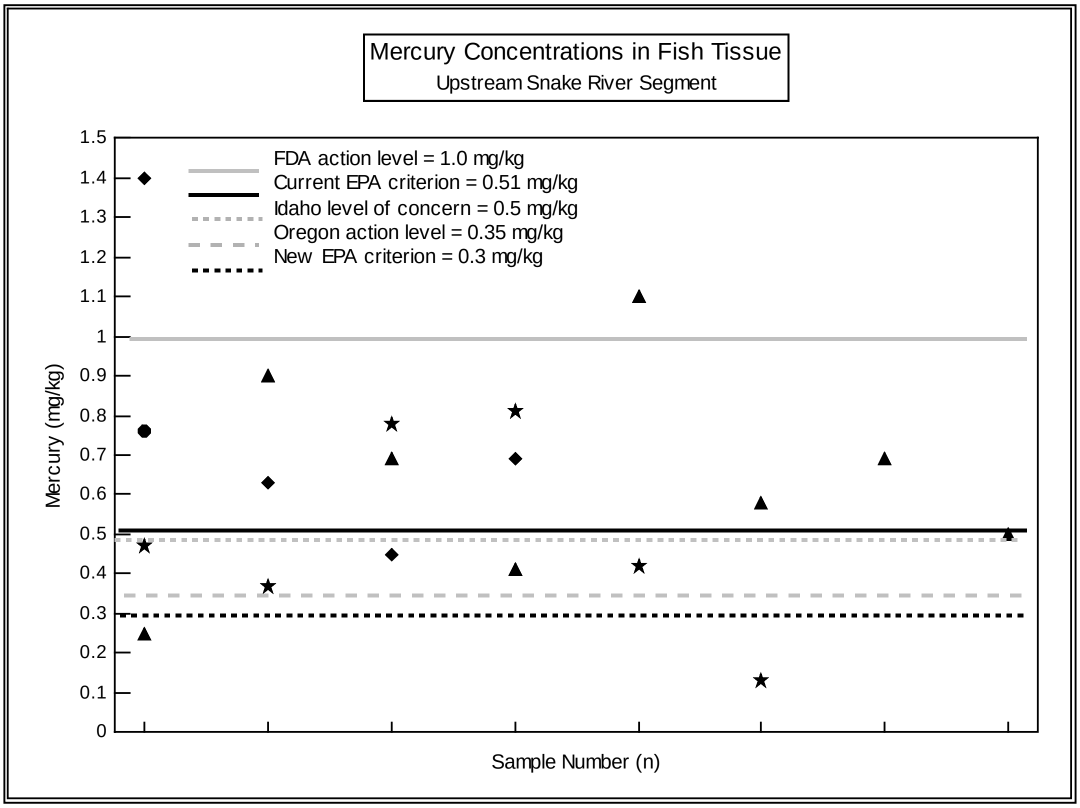
3.1.6 Data Available for the Snake River - Hells Canyon Reach

Mercury data available to this TMDL effort are almost exclusively in the form of fish tissue concentrations. Few data points identifying water column concentrations of mercury are available. Water column data are reported as <0.1 ug/L (Rinella *et al.*, 1994) or are reported as "below the detection limit" of 0.5 (the majority of the data set) or 0.2 ug/L, and were collected before 1990. There are 23 water column samples collected in 1990 that reported concentrations below detection limits of 0.2 ug/L mercury (US EPA STORET). Additionally, information collected by the City of Fruitland as part of the monitoring associated with the City's wastewater treatment plant show three data points for the Snake River (near the discharge point of RM 373). All samples were taken early in 2002 and show water column mercury concentrations in the Snake River to be less than the detection limit of 0.010 ug/L. These values are below the preliminary water column target of 0.012 ug/L established by the SR-HC TMDL.

Mercury data is available from the 1970's and the 1990's. However, due to substantial changes land management, sampling and analytical techniques and dramatic improvements in detection limits, the data collected in the 1990's is assumed to be more representative of actual conditions than that collected in the 1970's. Data collected in the 1970's are discussed in a general fashion within this section. Data from the 1990's are used as a basis for determining designated beneficial use impairment and management/control measures appropriate for the system. Data are shown in Figure 3.1.1 and Table 3.1.2.

Studies conducted in the 1970's (Benson *et al.,* 1976; Maret, 1995) characterized mercury concentrations in fish populations in Brownlee Reservoir (76 samples) and the Downstream Snake River (18 samples) segment as compared to upstream populations in the Snake River (31 samples).

The data collected in the 1990's contain a small fish tissue methylmercury data set for the Upstream Snake River segment (21 data points), a larger fish tissue methylmercury data for the Brownlee Reservoir segment (129 data points), and a single data point for the Downstream Snake River segment. There are no known fish tissue methylmercury data available for the Oxbow Reservoir or Hells Canyon Reservoir segments. No measured water column and little sediment mercury data are available to this effort. Water column data indicate only that concentrations were below the below detection limits, they do not give quantitative, measured concentration values.



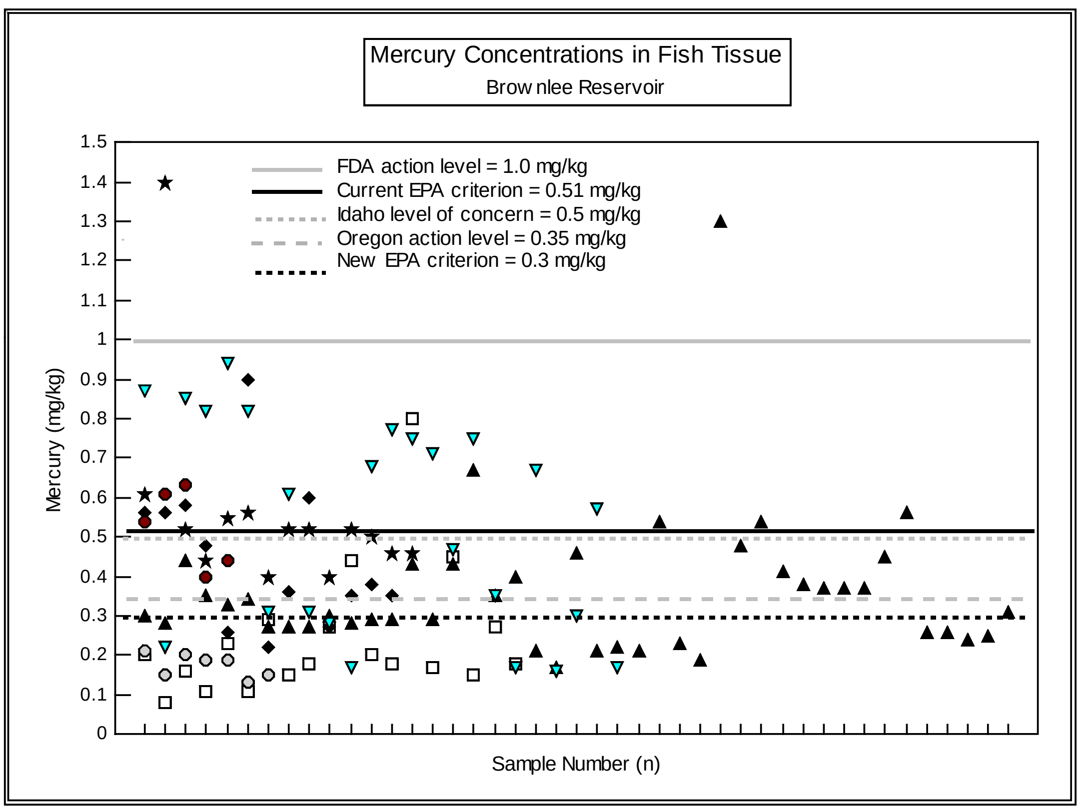


Figure 3.1.1. Mercury concentrations in fish tissue samples from the Upstream Snake River (RM 409 to 335) and Brownlee Reservoir Segments of the Snake River - Hells Canyon TMDL reach.

Table 3.1.2. Mercury data available for the Snake River - Hells Canyon TMDL (1970 through 1997).

Sample Site	Sample Group	Fish species	Year*	Average Hg (mg/kg wet weight)	n
Upstream	OSU	Channel Catfish	1970	0.61	11
Brownlee Res.	OSU	Channel Catfish	1970	0.97	5
Brownlee Res.	IDFG	Largemouth Bass	1970	0.37	3
Brownlee Res.	IDFG	Smallmouth Bass	1970	0.53	2
Brownlee Res.	IDFG	Bluegill	1970	0.60	1
Brownlee Res.	IDFG	Channel Catfish	1970	0.37	16
Brownlee Res.	IDFG	Carp	1970	0.24	1
Brownlee Res.	IDFG	Pike Minnow	1970	0.73	1
Brownlee Res.	IDFG	Sucker	1970	0.30	9
			Average	**0.51**	**38**
Upstream	IDFG/IDHW	Catfish	1975	0.33	20
Upstream	IDFG & Others	Water	1975 to 1977	<0.5 ug/L	72
Upstream	IDFG & Others	Water	1977 to 1987	<0.5 to <0.2 ug/L	67
Upstream	IDFG & Others	Water	1987 to 1989	<0.2 ug/L	19
Brownlee Res.	IDFG/IDHW	Idaho Catfish	1975	0.50	20
Brownlee Res.	IDFG/IDHW	Idaho Bass	1975	0.64	18
			Average	**0.57**	**38**
Hells Canyon	IDFG/IDHW	Idaho Bass	1975	0.79	18
Upstream	USGS	Carp	1990	0.79	4
Upstream	USGS	Channel Catfish	1990	0.64	8
Upstream	USGS	Smallmouth Bass	1990	0.50	6
Upstream	USGS	Crappie	1990	0.24	1
			Average	**0.62**	**19**
Upstream	USGS	Whole Water	1990	<0.1 ug/L	2
Upstream	USGS	Whole water	1989	<0.5 ug/L	3
Upstream	USGS	Whole water	1989	<0.2 ug/L	6
Upstream	USGS	Sediment	1990	0.02 ug/g	2
Brownlee Res.	IDEQ	Smallmouth Bass	1994	0.56	14
Brownlee Res.	IDEQ	Carp	1994	0.60	13
Brownlee Res.	IDEQ	Catfish	1994	0.34	42
Brownlee Res.	IDEQ	Black Crappie	1994	0.24	19
Brownlee Res.	IDEQ	White Crappie	1994	0.53	24
Brownlee Res.	IDEQ	Yellow Perch	1994	0.54	5
Brownlee Res.	IDEQ	Rainbow Trout	1994	0.19	7
			Average	**0.39**	**124**

Sample Site	Sample Group	Fish species	Year*	Average Hg (mg/kg wet weight)	n
Brownlee Res.	USGS & others	Whole water	1990 to 1996	< 0.2 ug/L	23
Upstream	USGS	Sediment	1997	0.04 ug/g	1
Brownlee Res.	USGS & IPCo	Largescale Sucker	1997	0.11	1
Brownlee Res.	USGS & IPCo	Carp	1997	0.32	1
Brownlee Res.	USGS & IPCo	Smallmouth Bass	1997	0.29	1
Brownlee Res.	USGS & IPCo	Crappie	1997	0.27	1
Brownlee Res.	USGS & IPCo	Channel Catfish	1997	0.33	1
			Average	**0.26**	**5**
Brownlee Res.	USGS	Sediment	1997	0.10 ug/g	2
Hells Canyon	USGS & IPCo	Largescale Sucker	1997	0.03	1
Upstream	USGS & IPCo	Channel Catfish	1997	0.21	1
Upstream	USGS & IPCo	Largescale Sucker	1997	0.07	1
			Average	**0.14**	**2**

(*****NOTE: Data collected prior to 1989 to 1990 may show higher levels of error due to differences in sampling and analysis as compared to current technology. Data in this table are from Benson, 1976; Gebhards *et al.*, 1971; Maret, 1995; Rinella *et al.*, 1994; Clark and Maret, 1998; IDEQ, 1994; IDFG-IDHW, 1971 to 1979; IPCo, 2000d; Buhler, 1971; Buhler *et al.*, 1971.)

All fish tissue samples collected from this reach were positive for mercury. A summary of the data show that the Oregon and Idaho levels of concern were exceeded by 80% (0.35 mg/kg) and 52% (0.5 mg/kg) respectively. Both states have acted to issue fish consumption advisories based on these exceedences. The US FDA action level for fish tissue (1.0 mg/kg) was exceeded in less than 10% of the fish tissue samples taken from the Upstream Snake River segment, and less than 3% of the fish tissue samples taken from the Brownlee Reservoir segment. The very limited data set available show no (0%) measured exceedences of the 0.050 ug/L US EPA water column criteria, however, detection limits were above this value by almost an order of magnitude in most cases.

Fish tissue methylmercury data collected in the Upstream Snake River (n = 20) segment show the highest fish tissue methylmercury concentrations in fish taken from the area of the mouth of the Owyhee River (0.73 mg/kg, n = 3), followed by the fish taken from the area of the mouth of the Weiser River (0.64 mg/kg, n = 3). These findings correlate well with the relative levels of natural geological mercury deposits identified and mining activities within these drainages, as compared to the SR-HC reach in general.

Elevated mercury concentrations in fish tissue from the Upper Snake River Basin were identified by Maret (USGS, Maret, 1995) in an intensive evaluation of existing data (1970 to 1990). Mercury concentrations from most sites exceeded the US Fish and Wildlife National Contaminant Biomonitoring Program (NCBP) baseline concentration of 0.11 ug/g, but did not exceed the US FDA action level of 1.0 mg/kg for fish consumption. All fish tissue data from the Snake River show concentrations above the detection limits in all cases except samples from the

Snake River at Flagg Ranch (< 0.05 mg/kg wet weight (Maret, 1995)), the Snake River at Minidoka (< 0.1 mg/kg wet weight (Clark and Maret, 1998)) and the Snake River at Kimberly (< 0.1 mg/kg wet weight (Clark and Maret, 1998)). The areas where fish tissue mercury concentrations were below detection limits correlate well with sediment mercury concentrations, which were below the detection limits only in the Minidoka and Blackfoot areas (both < 0.02 mg/kg (Clark and Maret, 1998)).

Warmwater and nongame species in Idaho were found to contain approximately twice the concentration of mercury as found in coldwater game fish species (Gebhards *et al.*, 1971). This indicates a relationship between diet and age, and mercury accumulation. Fish that are piscivorous (eat other fish) generally contain higher levels of mercury than fish that eat mainly plankton and insects. Some fish (such as rainbow and cutthroat trout) convert from a plankton/insect diet to a small fish diet after reaching a certain age or weight. Therefore older fish, and fish whose diets consist mainly of other fish should be avoided. Fish populations, in association with those human populations most at risk for injury due to mercury consumption, are targeted by the fish consumption advisories in place.

Gebhards (1971) states that geological sources of mercury are probably the major contributors to mercury residues in fish in the SR-HC area where anthropogenic activity is limited. The Oregon fish consumption advisory states that “the mercury in fish is thought to be from natural volcanic and geothermal sources in the upper drainage areas, possibly influenced by historical mining practices”. This statement is substantiated by the evaluation of proportional source loads within the SR-HC system.

Some bed sediment mercury information is available for several sites in the Upstream Snake River and Brownlee Reservoir segments. Mercury concentrations in bed sediments of the Snake River upstream of CJ Strike Reservoir range from 0.035 parts-per-million (ug/g) near Blackfoot to 0.09 parts-per-million (ug/g) near Buhl (Maret, 1995).

Mercury in bed sediments sampled by the USGS in Brownlee Reservoir near the inflow of the Burnt River and at Mountain Man Lodge (RM 310) (Clark and Maret, 1998) in 1997 were less than 0.174 parts-per-million (mg/kg), the threshold effects level (TEL) and 0.486 parts-per-million (mg/kg), the probable effects level (PEL) in all cases. The TEL and PEL are concentrations levels published by the National Oceanic and Atmospheric Association (NOAA) for the protection of benthic life.

The CH2MHill report (IPCo, 2000d) identified sediment mercury levels and associated particle sizes within the SR-HC reach. Particle size is an important factor in evaluating the distribution of mercury in sediments as smaller particle sizes have exponentially greater surface areas and are therefore likely to carry much larger adsorbed loads of trace metals and organic compounds. Clays and silts, commonly made up of very fine particles, generally have much higher concentrations of adsorbed constituents than coarser-grained sediments (IPCo, 2000d). Samples were taken from RM 397, downstream to Brownlee Dam (RM 285) including the mouth of the Owyhee, Boise, Malheur, Payette, Weiser, Burnt and Powder rivers. Samples were taken approximately every five miles from RM 340 to RM 285. Three deep core samples were extracted between RM 320 and RM 325 (within Brownlee Reservoir). Samples were collected from December 1998 to January 2000. Deep core samples included materials from approximately 10 feet below the 1952-surveyed water-surface elevation, which represents pre-impoundment conditions.

Data collected in this study showed a generally increasing trend in mercury concentration upstream to downstream. In the lower reservoir (RM 285 through 310) where the percentage of fine particles was the highest (6 samples), no concentrations exceeded the mercury PEL of 0.486 parts-per-million (mg/kg). The TEL (0.174 parts-per-million (mg/kg)) was exceeded for all samples.

In the upper reservoir (RM 312 through 336, 7 samples) the highest concentrations of mercury were observed at RM 335. The TEL was exceeded at this location, but not the PEL. The sediment collected at this location contained essentially no fine particles. This suggests that the mercury is present in either its native form or as cinnabar (HgS) (IPCo, 2000d) and is most likely deposited in this stretch through erosion and transport processes.

In the Upstream Snake River segment (RM 340 to 397, 11 samples), the TEL was exceeded at RM 340 only. This sample, located close to the one discussed at RM 335 above, contained both fine and coarse particle sizes but was analyzed as a composite. Therefore, the higher mercury levels may be due to the coarse grain sizes as at RM 335. The TEL for mercury was not exceeded in any of the tributary samples (IPCo, 2000d).

In the deep core samples (RM 320 to 325, 36 samples from 3 separate cores), none of the samples exceeded the TEL or PEL for mercury, indicating that the majority of mercury loading is probably associated with sediment erosion, transport and deposition within the SR-HC drainage rather than with strata associated directly with the SR-HC channel in Brownlee Reservoir.

Differences between this study and that undertaken by the USGS (Clark and Maret, 1998) are not necessarily indicative of reduced levels of mercury in the bed sediments within the SR-HC reach due to differences in the analytical technique applied. The digestion procedure used to prepare solids for trace metal analysis by the USGS was a more aggressive technique than that used by the CH2MHill study (IPCo, 2000d). A more aggressive digestion step can result in the dissolution of a greater proportion of the inorganic mercury in a sediment sample than that dissolved by a less aggressive digestion procedure. Therefore, reported concentrations would be expected to be higher for the analysis employing the more aggressive dissolution technique.

3.1.7 Determination of Mercury Loading

Determination of pollutant loading to a surface water system is generally accomplished through an association of concentration and flow values. Without the availability of measured water column concentration data for the SR-HC system, alternative methods of assessing mercury loading have been investigated. Without measured data for water column concentrations in the system, relative loading estimates and frequency of fish tissue target exceedences have been used as general indicators of the level of concern and actions necessary. Table 3.1.3 shows the identified sources of mercury to the SR-HC system and the relative contribution, measured or calculated of each. It should be noted that this information is preliminary, based on data and information currently available and may not be representative of the trends identified in the final SR-HC mercury TMDL.

Table 3.1.3. Identified sources of mercury loading to the Snake River - Hells Canyon reach and the relative contribution to total loading.

Source	Timeline	Data Type	Concentration or Potential Load	Relative Proportion of Measured Total
Seed treatments	Historical	Calculated	Estimated 8,164 kg total (0.013 kg/acre)	Unknown – assumed very small
Mercury in land applied domestic wastewater sludges	Current	EPA guidance	Negligible	Negligible
Landfills	Current	EPA guidance	Negligible	Negligible
Industrial processes	Current	EPA guidance	Negligible	Negligible
Mining	Legacy	Literature value	Up to 5 mg/kg tailings	Unknown – assumed moderate to high
Mining	Current	Monitored	No direct discharge	Unknown
Air Deposition - SR-HC direct drainage	Current	EPA guidance	380 to 5,110 kg/year	Unknown – estimated to be substantial
Air Deposition - Snake River Basin	Current	EPA guidance	380 kg/year	Unknown – estimated to be substantial
Ash Grove Cement Plant	Current	Monitored	49.5 kg/year	Small
Coal-Fired Power Plant	Current	Monitored	84.5 kg/year (at 100% capacity)	Small
Tributary loading (non-mining anthropogenic)	Current	Monitored – Water Column	Below detection limits	Unknown – assumed small
Natural loading – Owyhee basin	Historic and current	Monitored rock/soil concentrations	0.1 to 565.0 mg/kg in geologic deposits	Assumed moderate to high given richness of mineral deposits identified
Sediment loading – In channel values	Historic and current	Monitored rock/soil concentrations	0.02 to 0.05 mg/kg from measured data	Unknown – assumed moderate to high
Natural loading – In channel values	Historic and current	Monitored US rock/soil concentrations	0.02 to 0.625 mg/kg	Unknown – assumed moderate to high

Where sufficient data is available, bioaccumulation factors can be calculated for fish species in a mercury-enriched system. Preliminary bioaccumulation factors were developed by US EPA for application on a nationwide basis. However, under peer review, it was determined that these factors contained sufficient variability that they should not be applied in a generalized fashion (US EPA, 2001b). Peer review yielded the following findings and recommendations:

1. Bioaccumulation of methylmercury is highly site-specific in nature in aquatic environments
2. The peer reviewers recommended “developing methylmercury BAFs on a more local or regional scale if not on a site-specific basis…”
3. “After considering various issues about mercury fate in the environment…and the BAF peer review comments, EPA concluded that it is more appropriate at this time to derive a fish tissue…residue water-quality criterion for methylmercury than a water column based water quality criterion.”

The recommendation was made that site-specific bioaccumulation factors be developed for systems of concern. Unfortunately, the data available at this time is not sufficient to develop site-specific methylmercury bioaccumulation factors for the SR-HC reach. Therefore, water column concentrations cannot be calculated directly from the available fish tissue data.

Similarly, in response to recent advances in analytical technology and better understanding of methylmercury transport and uptake in living systems, the State of Idaho is initiating a review and potential revision of the current action level for methylmercury in fish tissue. Oregon is willing to participate in this review. The associated guidelines for issuing fish consumption advisories are also currently undergoing review. New action levels and guidelines are expected to be identified late in 2003 (personal communication, M. Wen, IDHW-EHS, May 2001).

Known designated beneficial use impairment due to mercury concentrations within the SR-HC reach is related to the designated use of fishing. This use is not fully supported due to elevated concentrations of mercury identified in fish tissue in the Upstream Snake River and Brownlee Reservoir segments. Elevated mercury concentrations in fish tissue represent a risk for both humans and wildlife consuming fish tissue.

3.1.8 Load Allocations and Other Appropriate Actions

Using the target water column concentration of 0.012 ug/L, a load capacity can be calculated (Table 3.1.5). However, calculation of an existing load or load allocation is not possible due to lack of water column data. Additionally, while relative load comparisons can be estimated, there are not sufficient data available to quantify the loading from legacy mining activities relative to natural loading within the SR-HC system. These assessments will be accomplished as part of the 2006 mercury TMDL.

3.1.9 Determination of the TMDL

Due to the uncertainty of back calculation from fish tissue methylmercury data, and the lack of water column mercury data for the SR-HC reach, a TMDL load cannot be calculated at this time.

The DEQs have assessed the data available (primarily fish tissue data) and do not feel that a load can be accurately back calculated. Current EPA guidance for calculating air deposition-based loading alone would constitute 92% of the allowable calculated capacity. The DEQs do not believe that this accurately characterizes the system. More data is needed to make an accurate assessment.

Due to the magnitude of these concerns, IDEQ and ODEQ have determined it is in the public interest to reschedule the mercury TMDL for Brownlee Reservoir. IDEQ has rescheduled this mercury TMDL to 2006 in order to gather additional data to better determine the sources and extent of mercury contamination. This change has been approved by the US EPA. This timeline is in compliance with ODEQ’s existing schedule.

The state of Oregon is developing capability to model site-specific bioaccumulation factors. Also, Oregon's mercury TMDL is not due until 2006. This schedule change will allow a better use of these capabilities and the opportunity to collect additional data.

Both Idaho and Oregon have interim measures in place to deal with mercury contamination such as sediment controls and fish consumption advisories. It is the opinion of the DEQs that this schedule change will not present an adverse impact to the SR-HC TMDL reach.

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3.2 Nutrient Loading Analysis

3.2.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. Because the SR-HC TMDL is a bi-state effort, the most stringent of each state's water quality standards have been identified as the targets for this TMDL. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met.

The Upstream Snake River segment (RM 409 to 335), the Brownlee Reservoir segment (RM 335 to 285) and the Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL reach are listed for nutrients on the state 303(d) lists for this TMDL. The water quality standards and guidance values identified for excess nutrients in the SR-HC TMDL are narrative criteria that address both the direct effects of elevated nutrient concentrations and the indirect effects of increased algal growth. These criteria require that nutrients shall not exceed quantities that impair designated beneficial uses, or cause visible slime growths or other nuisance aquatic growths that impair designated beneficial uses. Designated beneficial use impairment by excess nutrients is also linked to low dissolved oxygen concentrations through the growth and decay of algae, other aquatic plants and organic material resulting from elevated nutrient concentrations and loading.

A narrative standard for nutrients is appropriate given that the associated problems (excessive growth, low dissolved oxygen, etc.) can occur under a range of concentrations and are related to system characteristics such as flow, temperature, water column mixing, light penetration and water depth. Interpretation of the narrative standard on a site-specific basis is necessary to identify targets that will be protective of designated beneficial uses within the listed segment. The designated beneficial uses determined to be most at risk from excess nutrients were those associated with recreation and aquatic life. Direct effects on aesthetics and recreational use and indirect effects on aquatic life in the SR-HC TMDL reach are linked to excessive nutrient loading. A more detailed discussion of these concerns is included in the Subbasin Assessment for the SR-HC TMDL.

US EPA previously established guidelines for nutrient concentrations in surface waters specific to those waters discharging into lakes or reservoirs (0.05 mg/L total phosphorus) and those waters not discharging into lakes or reservoirs (0.10 mg/L total phosphorus). These guidelines have since been updated by US EPA with the release of ecoregional guidance values, and nutrient criteria establishment guidance (US EPA, 2000d). Additional methodology is available from other regions of the United States for the identification of algal biomass and chlorophyll *a* targets protective of designated beneficial uses. (Chlorophyll *a* can be used as a surrogate for algal biomass determination.) This guidance was used as an initial starting point for the identification of target concentrations for nutrients in the SR-HC TMDL. Available data from the SR-HC reach and other appropriate segments of the Snake River were evaluated to determine what instream concentrations would result in attainment of water quality standards and support of designated beneficial uses. Both the riverine and the reservoir segments were evaluated.

3.2.1.1 Snake River - Hells Canyon TMDL Water Quality Chlorophyll *a* and Nutrient Targets.

A chlorophyll *a* target of 14 ug/L mean growing season concentration and a nuisance threshold of 30 ug/L chlorophyll *a* with exceedence threshold of no greater than 25 percent has been established as the chlorophyll *a* target for this TMDL. The associated nutrient concentration target established for the SR-HC TMDL is a water column concentration of total phosphorus no greater than 0.07 mg/L. These are seasonal targets that apply from May through September. A more detailed discussion of target determination is included in the following sections.

It is the opinion of IDEQ and ODEQ that:

- These targets represent a valid interpretation of narrative standards.
- These targets will be protective of both recreation and aquatic life uses and water quality, and will thus meet the requirements of the CWA.
- Attainment of these targets, in coordination with the other water quality targets identified by this TMDL will result in full support of the designated beneficial uses within the system.

There has been a substantial amount of discussion within this TMDL process regarding the application of total phosphorus targets as opposed to ortho-phosphate targets. While it is recognized that dissolved ortho-phosphate represents the phosphorus fraction that is the most readily available for growth, it is also understood that ortho-phosphate is not a conservative parameter instream. Ortho-phosphate is a dynamic component of the water column and concentrations can change dramatically in a short distance or time due to growth or die-off of algal blooms and variation in dissolved oxygen concentrations. Ortho-phosphate can convert between forms readily under favorable water column conditions and may not be an accurate representation of the pool of phosphorus available for biological uptake.

3.2.2 Designated Beneficial Use Impairment

The designated beneficial uses determined to be most at risk from excess nutrients were those associated with aesthetics, recreation and aquatic life. Additional concerns related to excessive nutrient loading include risks associated with public drinking water supplies in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach.

3.2.2.1 Recreational Use and Aesthetics.

Direct effects associated with recreational uses include decreased utilization of the SR-HC system or portions thereof due to unfavorable water color, low water clarity and unpleasant odor. Indirect effects associated with aquatic life uses in the SR-HC reach include low dissolved oxygen levels deep in the water column due to the decomposition of algae and other aquatic plant materials and high in the water column due to diurnal effects associated with substantial algae blooms. High pH levels often associated with low dissolved oxygen due to decomposing organic matter have not been observed to occur in the SR-HC TMDL reach, most probably due to the buffering effect of natural mineral compounds dissolved in the water.

A review of concerns related to excess nutrient levels in the SR-HC reach shows that excessive aquatic growth (mostly algae blooms) is commonly observed in the Upstream Snake River segment (RM 409 to 335) and sections of the Brownlee Reservoir segment (RM 335 to 285) during late spring and early summer.

IDEQ has received a number of personal accounts and complaint calls regarding the condition of the Upstream Snake River segment (RM 409 to 335), particularly between the inflow of the Boise River (RM 396.4) and Farewell Bend (RM 335). The majority of the information was received as personal communication associated with recruitment for public participation in the SR-HC TMDL process and during public meetings for the Subbasin Assessment for the SR-HC TMDL. Additional comments were associated with posted public notices for SR-HC PAT meetings. Several complaint calls unrelated to the SR-HC TMDL effort have been received by IDEQ in regards to perceived poor water quality and unpleasant odor.

The majority of people offering information stated that the level of algal growth in the river has been increasing over the last 20 years and is now at a point where they will not swim or allow members of their families to swim in the water over the summer season. Several individuals specifically stated that they had previously used the Snake River near Weiser and Brownlee Reservoir for recreation but that during the last 10 to 15 years they have recreated in the Oxbow and Hells Canyon reservoirs instead as the amount of algal growth was less and their general impression of water quality in the downstream reservoirs was more favorable.

References to unfavorable water quality in regards to boating were fewer in number than those regarding swimming. In general complainants indicated that while they still use the river for boating, they have reduced the number of visits (usually during summer months) because of the added maintenance and cleaning required due to algal growth, and a general perception of poor water quality.

Additionally, several individuals referred to unfavorable odors associated with the water in this section of the Snake River and several referred to a decline in fishing success and quantity.

While the decrease in recreational-use hours described in these comments is difficult to quantify, and acknowledging that the complaints received do not necessarily constitute a representative sampling of recreational users on the SR-HC TMDL reach of the Snake River; they do indicate that there has been a negative effect on recreational use within the SR-HC TMDL reach.

An overall assessment of water quality was conducted by IDEQ during July and August of 2001 (a low water year). The Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir were surveyed visually at several different locations for aesthetic water quality conditions and general perception of visual water quality. A general increase in turbidity and coloration intensity is apparent from upstream to downstream in the Upstream Snake River segment (RM 409 to 335) as documented in the series of photos in Figure 2.3.1. These photos (taken June 2001) illustrate the change in water clarity and color in the mainstem Snake River from Marsing (RM 425) immediately upstream of the SR-HC TMDL reach, to Nyssa (RM 385), midway through the Upstream Snake River segment of the SR-HC TMDL reach, to Weiser (RM 351.2), approximately 16 miles upstream of the headwaters of Brownlee Reservoir. A decrease in aesthetic water quality is evident in these photos. The increase in turbidity and coloration, as

Figure 3.2.1. Photos illustrating change in water clarity and color in the mainstem Snake River from Marsing (RM 425) to Nyssa (RM 385) to Weiser (RM 351.2).

well as odor are most likely due to a combination of algae and other suspended sediment in the water column.

As aesthetic water quality and public perception are difficult to measure directly, those characteristics of water that are generally considered unappealing were evaluated. Dominant factors in the perception of water quality are coloration, odor and level of aquatic growth. Because it is correlated with all of these factors, algae was identified as a good indicator of aesthetic water quality. A commonly employed surrogate measure of algal growth is chlorophyll *a*. Chlorophyll *a* was used as a mechanism or surrogate measure of aesthetic water quality for the purposes of this assessment.

Chlorophyll is the green pigment in plants associated with photosynthesis (the process where-by plants combine light energy, nutrients and carbon to generate organic matter). A measure of chlorophyll gives information on the relative amount of photosynthesizing plants that are in the water column. Traditional methods of chlorophyll analysis give a measure of all green pigments in plants whether they are alive or dead. More current technology allows chlorophyll measurements to be corrected to remove the byproducts of chlorophyll degradation. Thus pheophytin-corrected chlorophyll *a* concentrations can be measured that report only that portion of the total chlorophyll that was actively photosynthesizing when the sample was collected, therefore, corrected chlorophyll *a* can be used to determine the amount of living algae (and other living plant material) in the water column. The chlorophyll *a* data utilized in this loading analysis was (to the extent possible) pheophytin-corrected chlorophyll *a*.

Other sources of chlorophyll *a* in the SR-HC TMDL reach may include sloughed periphyton and entrained plant materials (aquatic plants, tree leaves, etc.). Chlorophyll *a* is very labile (unstable) and does not last long once the plant materials have become detached (senescent). Algae (planktonic algae and periphyton) are presumed to be the dominant source of chlorophyll *a* in the water column during the summer months. In this manner, corrected chlorophyll *a* measurements have been used as a surrogate measure for algal biomass in the SR-HC TMDL reach. Sloughing of periphyton during spring and late fall time periods has not yet been quantified so the relative chlorophyll *a* and biomass concentrations related to this occurrence is unknown.

In order to better evaluate what concentration of chlorophyll *a* (algae) was acceptable through public perception for recreational purposes, a review of literature references to chlorophyll *a* targets based on aesthetics was conducted. Several targets were identified (Table 3.2.1), covering a range of maximum allowable chlorophyll *a* concentrations from 15 ug/L to 50 ug/L.

While Table 3.2.1 does not represent an exhaustive list, it serves to illustrate a range of chlorophyll *a* values identified to be appropriate to support of aesthetic and recreational needs. It is important to note that these values represent maximum acceptable concentrations, not averages. Individuals recreating on surface water systems do not perceive “average” water quality, they see the instantaneous conditions and use these characteristics as the basis for their perception of water quality. Therefore, these guidance values were established as maximum concentrations to support aesthetic and recreation designated uses.

Table 3.2.1 Chlorophyll *a* guidance from other states and British Columbia for aesthetic and primary contact recreation.

Location	Chlorophyll *a*
Colorado	< 15 ug/L
New Hampshire	< 15 ug/L
Minnesota	< 20 ug/L
South Dakota	< 33 ug/L
North Carolina	< 40 ug/L
British Columbia	< 50 ug/L
New Mexico	< 50 ug/L

Mean chlorophyll *a* concentrations in the mainstem Snake River between Weiser (RM 351) and RM 325 (in the upstream portion of Brownlee Reservoir) are routinely greater than 50 ug/L. These target values were identified as appropriate by several states and British Columbia. These values were (for the most part) specific to primary contact recreation and aesthetic uses. They were developed to act as a numeric representation of the maximum chlorophyll *a* concentrations that recreational users of a water system would judge to be acceptable; or as values below which algae concentrations would not result in reduced recreational usage. These values were used as a general range in determining what appropriate levels of chlorophyll *a* may be within the SR-HC TMDL reach. They are not, however, the sole driver, as other designated beneficial use concerns are associated with excessive nutrient loading.

3.2.2.2 AQUATIC LIFE.

Data available show indirect negative effects on aquatic life in the form of low dissolved oxygen (in the reservoir complex) and high productivity levels (in both the Upstream Snake River segment (RM 409 to 335) and the upstream portion of Brownlee Reservoir).

Low dissolved oxygen concentrations have been documented in Brownlee Reservoir from as early as 1968 (IPCo, 1998a and 1998b) to the present. A major fish kill occurred in Brownlee Reservoir in July of 1990, involving all fish species, including sturgeon. Dissolved oxygen concentrations observed during this event indicate that anoxia in the upper end of Brownlee

Reservoir was the dominant cause of fish mortality (IPCo, 1999c). These data indicate that the designated uses of cold water aquatic life/salmonid rearing and related aquatic life uses are not being fully supported in the downstream portion of the Upstream Snake River segment and in Brownlee Reservoir.

Organic material (algae, detritus, etc.) produced and transported within the upper SR-HC TMDL reach is the primary cause of low dissolved oxygen in Brownlee Reservoir (IPCo, 1999d, 2000a, 2000e; IDEQ, 1993b), and potentially in the lower sections of the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach as well. Dissolved oxygen concentrations in Brownlee Reservoir need to increase substantially (by more than 4 mg/L in some conditions), in order to meet the SR-HC TMDL target of 6.5 mg/L for support of salmonid rearing/cold water aquatic life.

Brownlee Reservoir is a narrow, deep channel with a relatively short retention time. The deep sections of the reservoir, below the thermocline, are well below the photic zone and provide little growth potential. These deep layers (the hypolimnion) are relatively stagnant during stratification and experience little if any circulation or recharge during the summer months. The metalimnion (volume near the thermocline) and epilimnion (volume above the thermocline), however, experience greater turnover throughout the summer season. The metalimnion may occupy the lower depths of the photic zone and may experience some mixing due to reservoir releases and, to a lesser degree, wind action at the surface. The epilimnion occupies the upper reaches of the photic zone and experiences more surface-driven mixing.

Both the metalimnion and the epilimnion offer greater potential for habitat than the hypolimnion. The middle layers of the reservoir (the metalimnion and the epilimnion below the immediate surface layers) provide adequate temperature conditions throughout much of the summer. During late summer and early fall, cold water tributaries provide refugia for coldwater species living in the reservoir (Section 3.6). These upper layers (the upper column of the metalimnion and the lower volume of the epilimnion) represent the portion of the reservoir most likely to support aquatic populations. Improvements in dissolved oxygen in these areas will therefore provide greater, more immediate benefits to aquatic life within the reservoir. These areas have been targeted directly as high priorities for improvements in dissolved oxygen.

Areas of the hypolimnion are known to experience low dissolved oxygen as a result of chemical and biological processes associated with stratification. This phenomenon is recognized by Idaho State standards (IAC 250.02.a). Due to this occurrence, and the fact that they are located well below the photic zone of the reservoir, these deep waters represent less of a viable habitat than do the waters above the hypolimnion. Because of this, they have been targeted as a secondary priority for dissolved oxygen improvement.

3.2.2.3 ANOXIA AT THE SEDIMENT/WATER INTERFACE AND IN THE SUBSTRATE.

In addition to concerns centering on low dissolved oxygen concentrations in the water column, anoxia in the substrate represents a concern to aquatic life within the system. Many fish species, including white sturgeon and mountain whitefish deposit eggs at the sediment/water interface. Low dissolved oxygen from decaying algae and other organic matter presents a harmful or potentially lethal condition for these young fish. White sturgeon populations in the Upstream

Snake River (from Swan Falls to Brownlee Dam) are below the expected values (personal communication, J. Chandler, IPCo, August 2002). Low dissolved oxygen levels at the sediment/water interface may play a role in the reduced populations and low recruitment observed.

Elevated concentrations of chlorophyll *a* have been observed in the Upstream Snake River segment (RM 409 to 335) and the headwaters of Brownlee Reservoir (BCPW, 2001; IPCo, 1999d, 2000a, 2000e; IDEQ, 1993b). These levels indicate that substantial algal blooms occur consistently in this area. Additionally, excessive levels of periphyton have been observed in the Snake River at the USGS gage near the inflow of the Weiser River (personal communication, P. Woods, USGS, 2001). Decomposition of organic material from these algal blooms and other nutrient-induced growth deposited within the SR-HC TMDL system has been suspected to result in low dissolved oxygen levels within the sediments and at the sediment/water interface within the Upstream Snake River segment (RM 409 to 335) and the headwaters of Brownlee Reservoir.

As discussed previously, low dissolved oxygen associated with depositional areas in Brownlee Reservoir has been well documented (IPCo, 1999d, 1999g, 2000c; BCPW, 2001). Investigation of similar conditions in the Upstream Snake River segment (RM 409 to 335) is currently in progress.

No sediment/water interface or substrate dissolved oxygen data from the Upstream Snake River segment (RM 409 to 335) is available to this TMDL process at this time, however, data from artificial redd studies conducted upstream of RM 409 by IPCo in 1999 to 2000 and 2000 to 2001 (IPCo, 2001c) show that dissolved oxygen concentrations drop to very low levels (less than 2.0 mg/L) during the late spring and summer months at the sediment/water interface. Artificial redds were constructed at RM 450.4, 447.8 and 441.8. These locations are between Swan Falls and the upstream portion of the SR-HC TMDL reach.

Intergravel dissolved oxygen measurements collected in the artificial redds in 1999 to 2000 showed concentrations below 6 mg/L at RM 450.4 and 441.8 by late February, 2000. Dissolved oxygen concentrations at these two sites were below 4.0 mg/L by April 2000 and below 2.0 mg/L May through June of 2000 (data are not available for the summer months). Intergravel dissolved oxygen measurements in the artificial redd at RM 447.8 showed concentrations above 6 mg/L December 1999 through early May 2000. Dissolved oxygen concentrations below 6.0 mg/L were observed late May through June 2000 at this site (IPCo, 2001c).

Intergravel dissolved oxygen measurements were collected in the artificial redds at RM 450.4 and 447.8 during 2000 to 2001. These data showed concentrations below 6 mg/L at both sites by late March 2001. Dissolved oxygen concentrations at both sites were below 4.0 mg/L by April 2001 and below 2.0 mg/L May through June of 2001 (IPCo, 2001c).

Initial, qualitative assessments of the Upstream Snake River segment of the SR-HC TMDL reach (RM 409 to 335), have identified conditions similar to those observed in the Snake River at the location of these artificial redds (e.g. similar flow and temperature conditions combined with a thick layer of decomposing organic material located at the sediment/water interface). These initial, qualitative investigations, combined with the data collected by IPCo upstream, suggest that low dissolved oxygen concentrations similar to those observed in the artificial redds occurs at the sediment/water interface in the Upstream Snake River segment (RM 409 to 335). This is likely one of the factors contributing to the decline in white sturgeon populations in this segment of the Snake River.

3.2.2.4 Production of Methylmercury.

Of additional concern to this TMDL is the conversion of inorganic or elemental mercury within the SR-HC TMDL reach to methylmercury. While inorganic or sediment-bound mercury can be absorbed by aquatic organisms, the rate and efficiency of the uptake is much lower than that for methylated or organic mercury, which can easily enter the food chain (USGS, 1995). Many factors influence the form, concentration and transport of mercury in the environment, these include the concentration of dissolved organic carbon (DOC), the pH of the water system, and the concentration of dissolved oxygen in the water (Hurley, 1995).

Sediment samples collected and analyzed for mercury content in both the Upstream Snake River segment (RM 409 to 335) and the Brownlee Reservoir segment (RM 335 to 285) show that the highest concentrations of sediment-associated mercury are at RM 335 and RM 340. Both samples exceeded the threshold effects level (TEL) of 0.174 parts-per-million (mg/kg), the concentration level published by the National Oceanic and Atmospheric Association (NOAA) for the protection of benthic life. These elevated levels of mercury, when combined with organic material resulting from excessive algal growth and the associated organic matter in this area, represent a substantial potential for methylmercury production.

There is a relationship between mercury concentrations observed in bed sediments and those observed in the tissue of resident fish. Methylmercury produced in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285), has the potential to affect not only local aquatic life but also downstream species as well, as the methylmercury produced will be carried downstream by flowing water. Organic matter accumulating from algal growth and nutrient enrichment in the Upstream Snake River segment (RM 409 to 335) is of particular concern as it accumulates in the area between RM 340 and RM 320, the location identified as exhibiting the highest concentrations of sediment-associated mercury within the TMDL reach. This condition has the potential to exacerbate the conversion of inorganic mercury to methylmercury within this reach and contribute to higher methyl-mercury concentrations in the Hells Canyon Complex reservoirs and further downstream.

Low dissolved oxygen conditions in Brownlee Reservoir also have the potential to contribute to higher methyl-mercury concentrations in downstream waters.

All fish tissue data available in the SR-HC TMDL reach were positive for mercury. Water column data available were below the 0.050 ug/L concentration value established by the US EPA, however, detection limits were greater than the threshold limit by almost an order of magnitude in most cases so violations of the criteria could occur within these samples even though concentrations are reported as below the detection limit. The Oregon and Idaho levels of concern for methylmercury in fish tissue were exceeded by 80 percent (0.35 mg/kg) and 52 percent (0.5 mg/kg) respectively. Based on these data, both states have fish consumption advisories in place.

An evaluation of sediment and fish tissue data from the Snake River mainstem as a whole showed that in areas where sediment-associated mercury concentrations were below the detection limits, fish tissue concentrations were also (Section 3.1). All fish tissue data collected from the mainstem Snake River show concentrations above the detection limits except samples from the Snake River at Flagg Ranch (< 0.05 mg/kg wet weight (Maret, 1995a and 1995b)), the Snake River at Minidoka (< 0.1 mg/kg wet weight (Clark and Maret, 1998)) and the Snake River at Kimberly (< 0.1 mg/kg wet weight (Clark and Maret, 1998)), areas well upstream of the SR-HC TMDL reach. The areas where fish tissue mercury concentrations were below detection limits correlate well with sediment mercury concentrations. Sediment mercury concentrations below the detection limits were observed in the Minidoka and Blackfoot areas (both < 0.02 mg/kg (Clark and Maret, 1998)) only.

Warmwater and nongame species in Idaho were found to contain approximately twice the levels of methylmercury as found in coldwater game fish species (Gebhards et. al., 1971). This finding is of concern as the majority of fish species within the SR-HC TMDL reach are warm water fishes. Fish populations, in association with those human populations most at risk for injury due to mercury consumption, are targeted by the fish consumption advisories in place for both Oregon and Idaho within the SR-HC TMDL reach.

Deposition of organic matter on the surface of the river channel occurs throughout the Snake River system. Deposition within the Upstream Snake River segment (RM 409 to 335) occurs most efficiently in areas of reduced flow velocity (eddies, backwaters, pools, etc). Deposition within Brownlee Reservoir has been observed to occur in the upstream sections of the reservoir (RM 325 to 310). Both organic and inorganic materials are deposited in these areas. Decomposition of organic matter removes oxygen from the water column. This results in anaerobic conditions at the sediment/water interface. Under these conditions the conversion of inorganic mercury to methylmercury has been observed to occur more readily. Therefore, increased availability of methylmercury in the SR-HC TMDL reach can be directly related to the production and deposition of organic material (algae, periphyton, etc.), and associated anoxic or low oxygen conditions.

While data available to the SR-HC TMDL indicate that the dominant source of mercury is naturally occurring geological deposits which are (at best) difficult to control, the conversion of the inorganic mercury contained within these sediments to methylmercury (the form most related to health concerns for both aquatic life and humans) is related to available organic material and anoxic substrate conditions. Given the current understanding of the methylation process, reductions in organic matter within the SR-HC TMDL reach are possible, and are projected to result in reductions in the amount of methylmercury produced. Reductions in algal growth have a high priority in this TMDL as they represent one of the most effect mechanisms for control of mercury already within the SR-HC TMDL system in addition to the direct benefits to water quality that would result.

3.2.2.5 DOMESTIC WATER SUPPLY.

The US EPA identifies nutrient enrichment as a serious health problem in the context of drinking water supplies. Trihalomethanes are carcinogenic (cancer causing) compounds that can be produced when water containing organic compounds is chlorinated or brominated as part of the treatment and disinfection processes in drinking water facilities. The organic compounds commonly associated with the trihalomethane formation process are humic substances, algal metabolites and algal decomposition products (US EPA, 2000d). According to references in the recent US EPA nutrient guidance document for rivers and streams, the density of algae and the level of eutrophication in raw water supplies have been correlated with the production of trihalomethanes in drinking water (US EPA, 2000d).

In addition to the human health concerns associated with eutrophic drinking water supplies, taste and odor problems associated with algal growth have been reported nationwide. Many of the chemical compounds that algae secrete can result in unpleasant tastes and odors. These compounds are difficult to remove with standard equipment or treatment processes. They often require activated carbon treatment, direct, in-river treatment of the water supply or other such mechanism. Additionally, increased treatment costs from clogged filters, corrosion of intake pipes, increase in the amount of chemicals necessary to treat the water, increased back-flushing of filters and additional settling times to attain acceptable water quality can result from nutrient impairment of domestic water supplies (US EPA, 2000d).

Two cities within the SR-HC TMDL reach use the Snake River as a source of drinking water, the City of Ontario, Oregon (RM 369) and the City of Weiser, Idaho (RM 352). The designation of the SR-HC TMDL reach as a domestic water supply requires that the needs of this beneficial use be considered in the management of the SR-HC TMDL reach, namely, decreased total biomass to decrease the potential for trihalomethane production, decreased total biomass for reduction of filter clogging, reduction of nutrient concentrations to reduce pipe corrosion, and etc.

Finally, the production of neuro- and hepato-toxins by cyanobacteria (blue-green algae) blooms is of concern. When present at excessive concentrations cyanobacteria often produce toxins that can result in skin irritation to swimmers, and illness or even death in animals ingesting the water. The deaths of 23 cattle in Cascade Reservoir (located on the Payette River) were reported in 1993 due to excessive cyanobacteria blooms. This phenomenon is not confined to lake and reservoir systems, however, and has occurred previously in the Snake River. Two canine deaths due to ingestion of blue-green algal toxins were confirmed (November, 2000) and several others suspected (Fall 1999) below the Minidoka Dam along the Snake River between Rupert and Burley, Idaho (Eyre, 2001), approximately 265 miles upstream from the SR-HC TMDL reach.

3.2.2.6 ENDANGERED AND THREATENED SPECIES.

The portion of the SR-HC TMDL reach listed for excessive nutrients provides habitat for the Idaho spring snail, (*Pyrgulopsis idahoensis,* formerly *Fontelicella idahoensis* (Frest and Johannes, 2001)). Distribution includes the mainstem Snake River from RM 422 to 393 and from RM 372 to 340 (IPCo, 2001a). This snail species is listed as threatened under the Federal Endangered Species Act (ESA). It requires cold, clear, well-oxygenated water for full support. These snails have been observed to live on rocks and sediment at the sediment/water interface within the Snake River channel.

Given the information discussed above, and the current understanding of the SR-HC TMDL reach, it is the professional opinion of IDEQ and ODEQ that excessive nutrient levels are impairing designated beneficial uses in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Data available show impairment of aesthetic and recreational uses, and indicate a level of concern for cold water aquatic life/salmonid rearing, resident fish and aquatic life, domestic water supply designated beneficial uses within the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285). Impairment of the Oxbow Reservoir segment (RM 285 to 272.5) cannot be determined at this time but will be directly related to the water quality in Brownlee Reservoir due to inflow and retention characteristics. It is also the professional opinion of IDEQ and ODEQ that attainment of the SR-HC TMDL chlorophyll *a* target of 14 ug/L mean growing season concentration and a nuisance threshold of 30 ug/L chlorophyll *a* with exceedence threshold of no greater than 25 percent, combined with the nutrient target of less than or equal to 0.070 mg/L total phosphorus, in combination with other SR-HC TMDL pollutant targets will result in full support of the designated beneficial uses within the system.

3.2.3 Sources

Both natural and anthropogenic sources of phosphorus are known to be present in the SR-HC TMDL drainage. Anthropogenic loading includes both point and nonpoint sources. A brief overview of nutrient sources is discussed below. A more detailed description is available in the Subbasin Assessment for the SR-HC TMDL.

3.2.3.1 Natural Sources.

A general discussion of natural sources of nutrient loading is available in Section 2.2.4.3. Natural sources of nutrients include erosion of phosphorus-containing rock and soils through wind, precipitation, temperature extremes and other weathering events. Natural deposits of phosphorus (Hovland and Moore, 1987) have been identified in the Snake River drainage near Pocatello, Idaho (RM 731.2). Geological deposits in the Blackfoot River watershed (inflow at RM 750.6) contain phosphorus in sufficient concentrations that they have been mined. The Snake River flows through this area some distance upstream of the SR-HC TMDL reach.

In an effort to assess the potential magnitude of natural phosphorus concentrations in the mainstem Snake River due to these geological deposits, total phosphorus concentrations occurring in the mainstem near the Blackfoot and Portneuf River inflows (RM 750.6 and 731.2 respectively) were evaluated. Data was available for the Snake River near Blackfoot, Idaho (USGS gage # 13069500, RM 750.1) and for the Blackfoot and Portneuf Rivers (USGS, 2001a). The mainstem Snake River and these tributary river systems, where they flow through the natural mineral deposits represent a worst-case scenario for evaluation of natural phosphorus loading and were identified as potential sources of naturally occurring phosphorus to the SR-HC reach. USGS gaged flow data and water quality data from the 1970's to the late 1990's is available for the Blackfoot and Portneuf Rivers ((USGS gage # 13068500, and #13075500 respectively). Because both the mainstem and tributary watersheds have been settled for some time, and land and water management has occurred extensively, the data compiled represent both natural and anthropogenic loading.

Total phosphorus concentrations in the Snake River mainstem, measured near Blackfoot, Idaho (RM 750.1), from 1990 to 1998 averaged 0.035 mg/L (range = <0.01 to 0.11 mg/L, median =

0.03 mg/L, mode = 0.02 mg/L) (USGS, 2001a). Nearly 40 percent (23 samples) of the total data set showed total phosphorus concentrations less than or equal to 0.02 mg/L. Data represents year-round sampling. Winter sampling was slightly less frequent (approximately 19% of the total) than spring, summer or fall.

Natural phosphorus concentrations were not assessed as part of the Blackfoot River TMDL (IDEQ, 2001b). Total phosphorus concentrations in the Blackfoot River, measured near the mouth, from 1990 to 1999 averaged 0.069 mg/L (range = <0.01 to 0.43 mg/L, median = 0.04 mg/L, mode = 0.03 mg/L) (USGS, 2001a). Nearly 23 percent (12 samples) of the total data set showed total phosphorus concentrations less than or equal to 0.02 mg/L. Data represents year-round sampling. Winter sampling was less frequent (approximately 13% of the total) than spring, summer or fall.

Natural phosphorus concentrations were not assessed for the Portneuf River TMDL (IDEQ, 1999d). Total phosphorus concentrations in the Portneuf River, measured near the mouth, from 1990 to 1998 averaged 0.085 mg/L (range = <0.01 to 0.28 mg/L, median = 0.069 mg/L, mode = 0.03 mg/L) (USGS, 2001a). Nearly 21 percent (6 samples) of the total data set showed total phosphorus concentrations less than or equal to 0.02 mg/L. Data represents year-round sampling. Winter sampling represented approximately 22 percent of the total.

The fact that very low total phosphorus concentrations were observed routinely (more than 20% of the time) in the mainstem Snake River, the Blackfoot River and the Portneuf River, all watersheds with a high level of use and management show that the natural loading levels are likely below detection limit concentrations. The additional fact that these low concentrations were observed in watersheds in much closer proximity to the rich geological phosphorus deposits indicates that these deposits likely do not represent a significant source of high, natural loading to the SR-HC TMDL reach, located well downstream from the mineral deposits identified.

Given the above discussion, the natural background concentration for total phosphorus in the mainstem Snake River has been estimated as at or below 0.02 mg/L for the SR-HC TMDL reach. This value is based on the available data set. Data from the Snake River upstream of RM 409 was included in this data set to address the concern of enrichment of surface waters by the phosphoric deposits located in central and eastern Idaho (Hovland and Moore, 1987). Due to the fact that there are substantial anthropogenic influences in Snake River Basin, the lower 15th percentile value for total phosphorus concentration was selected as a conservative estimate of natural phosphorus concentration. In this manner, natural concentration levels for the mainstem Snake River were calculated conservatively. This initial estimate will be reviewed as additional data become available and revisions will be made as appropriate.

The estimated natural background loading concentration for the mainstem Snake River (0.02 mg/L) is most likely an overestimation of the natural loading but represents a conservative estimate for the purposes of load calculation. In addition, this concentration correlates well with other studies that have been completed and closely approximates the total phosphorus concentration identified for a reference system (relatively un-impacted) by the US EPA (US EPA, 2000d; Dunne and Leopold, 1978).

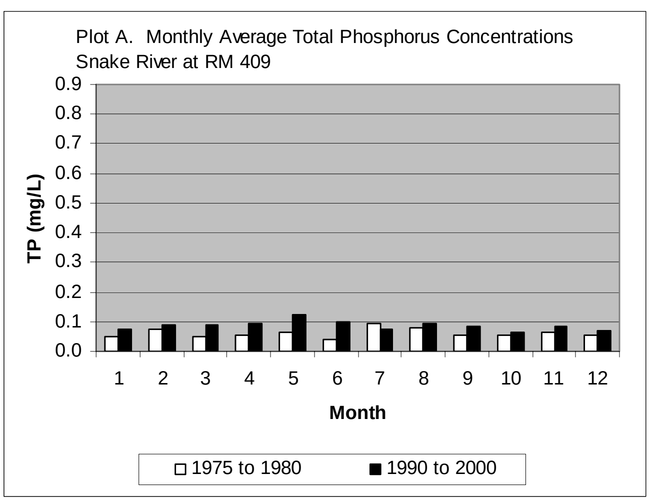
A necessary set of data to establish natural loading or concentration values for the tributary streams is not currently available. Therefore, natural background concentrations for all tributaries will be determined as part of upcoming TMDL development on the Weiser, Owyhee, and Malheur Rivers, and tributary implementation plans for the Payette and Boise Rivers.

3.2.3.2 ANTHROPOGENIC SOURCES.

Anthropogenic nutrient sources to the SR-HC TMDL reach include permitted point sources that discharge directly to the Snake River within the SR-HC TMDL reach (as listed in Table 2.5.0), nonpoint source discharges in the direct drainage, and man-made sources that discharge to tributaries of the SR-HC TMDL reach. Point source discharges to tributary systems are a recognized component of overall loading to the SR-HC reach, but are identified as nonpoint source tributary loading in this TMDL. Load calculations and load allocations will be made to the mouth of the tributaries and the tributary-specific TMDL process will determine point and nonpoint source load allocation mechanisms. Those point sources that discharge to tributary systems are not included in the point source loading calculations for the SR-HC TMDL.

Anthropogenic nonpoint sources of phosphorus in the SR-HC area include (among others) agricultural sources such as runoff from fertilized fields, sediment-bound transport from plowing, and flood and furrow irrigation, as well as organic enrichment; sediment-bound transport and organic enrichment from forestry sources such as logging and streambank disturbance; and urban/suburban sources including stormwater runoff, improperly functioning septic and sewer systems and lawn fertilizers.

Elevated phosphorus concentrations have been observed in the Upstream Snake River segment (RM 409 to 335), in the inflowing tributaries and in many of the agricultural drains where they enter the Snake River (US EPA, 1974; IDEQ, 1998a; IPCo, 1998a and 1998b; BCPW, 2001) as shown in Figure 3.2.2 plots a through j (multiple pages).



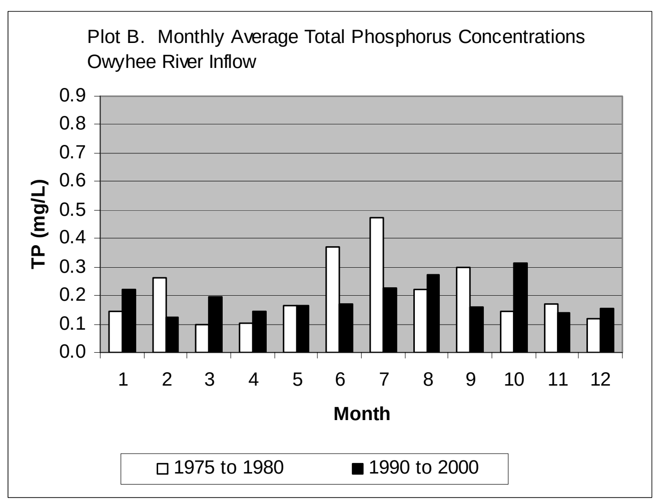
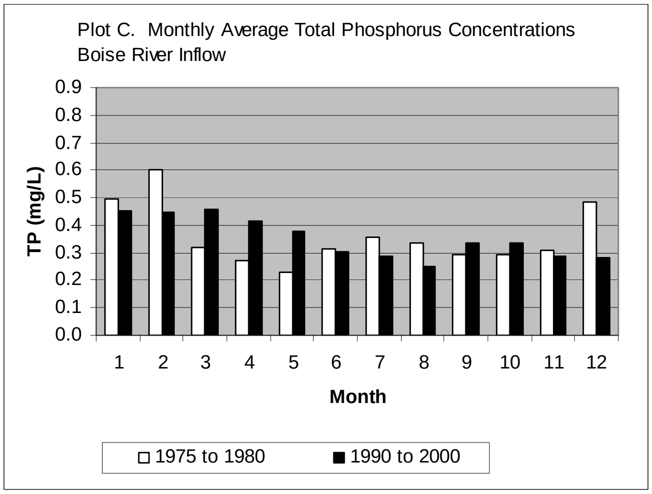
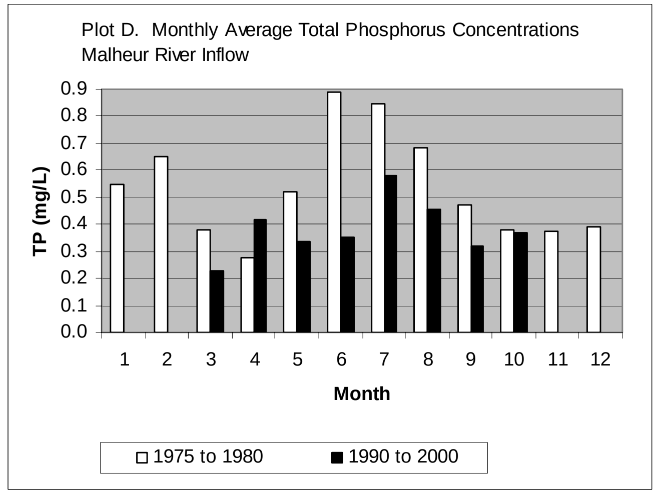
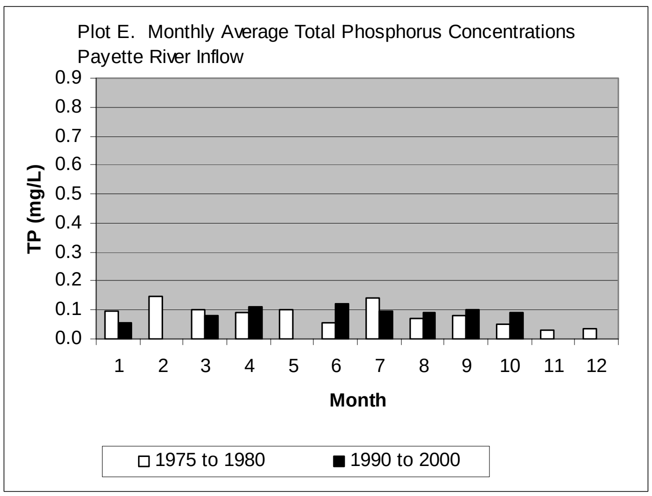


Figure 3.2.2. Mean monthly total phosphorus concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.







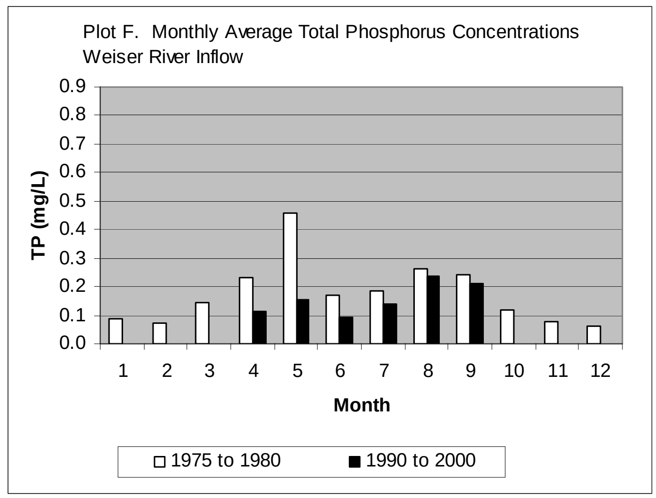


Figure 3.2.2. (cont.) Mean monthly total phosphorus concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

Concentrations tend to increase in correlation with the summer growing and irrigation season. The concentration data available represent the sum of natural and anthropogenic loading from the identified tributaries and mainstem locations. Data from 1975 to 1980 and data from 1990 to 2000 are summarized.

The Malheur River (plot D) shows substantial reduction in total phosphorus concentrations between 1975 to 1980 and 1990 to 2000. In most other cases, a level trend or a slight increase in concentration is observed between the two data sets. The data sets displayed do not contain equal numbers of data points for the 1975 to 1980 and 1990 to 2000 time periods.

In most cases, more data was available in the 1990 to 2000 time period than in the 1975 to 1980 time period. Lack of data or smaller than average data sets occurred in some years and at some locations. These limited data may not be representative of average conditions. Scales on all plots were normalized to allow for an easier comparison of relative concentration differences.

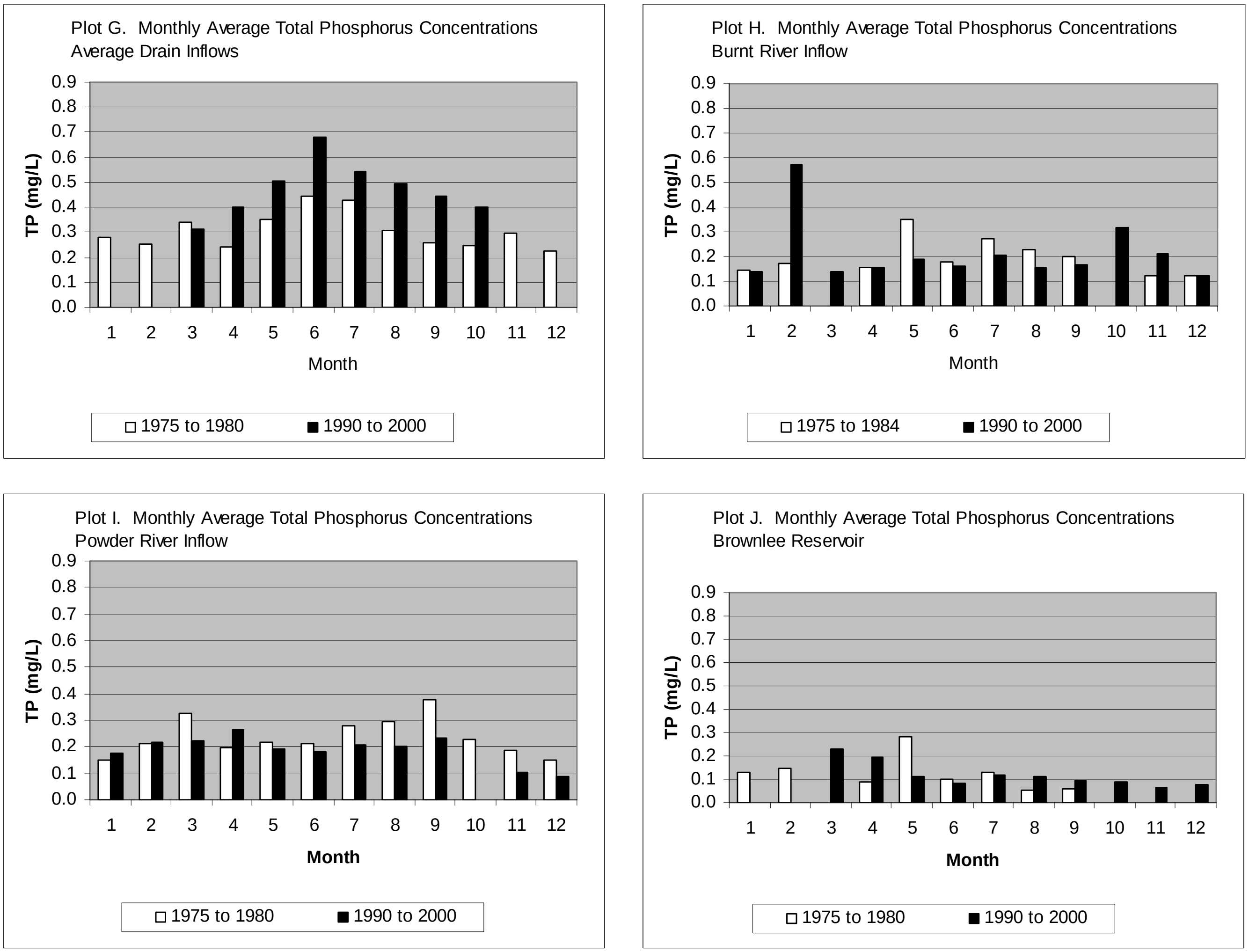


Figure 3.2.2. (cont.) Mean monthly total phosphorus concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

Studies performed throughout the United States have shown that "conditions that allow periphyton/plankton biomass to accumulate (i.e. adequate light, optimum current velocity for periphyton, sufficient water detention for plankton, as well as low loss to aquatic grazers) will not result in high biomass without sufficient nutrient supply. Nutrients, especially phosphorus, are the key stimulus to increased and high algal biomass" (US EPA, 2000d). This is supported by data collected in the Snake River system as shown in Figure 3.2.3. It is observed that lower phosphorus concentrations within the Snake River system correlate with lower concentrations of chlorophyll *a* than those observed at higher total phosphorus concentrations.

Conditions resulting in high water temperatures, elevated nutrient loading and low flow conditions are favorable to cyanobacteria species. Control of two of these three conditions is not feasible for the SR-HC TMDL. First, elevated water temperatures within the SR-HC TMDL

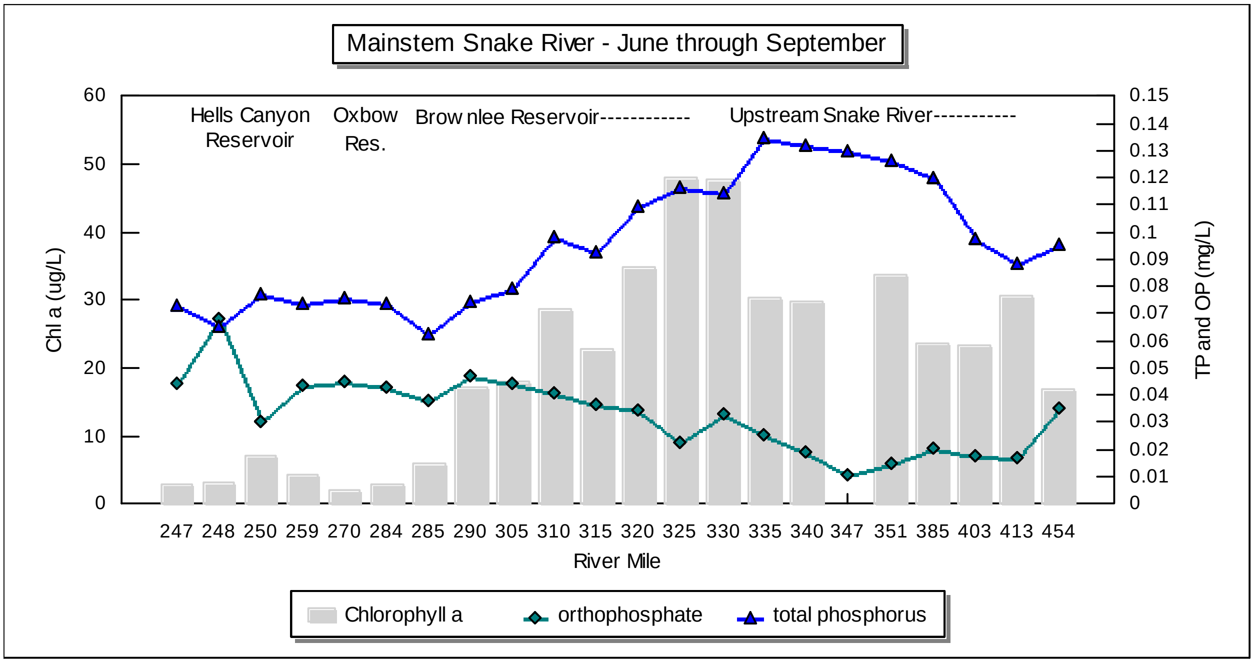


Figure 3.2.3. Spatial distribution of mean phosphorus and chlorophyll *a* concentration data within the Snake River - Hells Canyon TMDL reach (June through September, 1990 to 2000).

reach have been shown to be predominantly the result of natural atmospheric and non-quantifiable thermal loading. Second, changes to flow conditions are outside of the scope of this TMDL. The third condition, elevated nutrient loading, can be controlled under the auspices of the TMDL and implementation processes.

3.2.4 Transport and Delivery

The primary mechanism for nutrient transport in the SR-HC reach is surface and subsurface water flow. Nutrients can be dissolved in the water column or adsorbed onto the surface of soil and sediment particles, and organic matter. The sediment fractions most commonly associated with the greatest nutrient loading are the fine and very fine particles that have the largest surface area to volume ratio and therefore the largest adsorption capacity. These particles can be transported long distances before they drop out of the water column. Once deposited, these particles can act as a source of phosphorus enrichment in two ways: through direct re-entrainment of solid particles with an increase in flow, and through desorption of attached nutrients to the water column. This cycle is discussed in greater detail in the sediment loading analysis (Section 3.5) and the Subbasin Assessment (Section 2.2).

As with sediment loading, land use and management may influence nutrient transport and delivery within the watershed. Long-term saturation of soils can result in anoxic conditions that cause the release of adsorbed phosphorus. This can occur in flooded soils in the watershed, from intentional flooding as is used in some irrigation practices, or unintentional flooding such as in a poorly drained lawn or garden area. It also occurs at the sediment/water interface in anoxic areas of a reservoir system. This type of de-sorption results in a form of phosphorus that is much more readily available for uptake by aquatic plants.

3.2.5 Data Available for the Snake River - Hells Canyon TMDL Reach

As discussed in the general loading assessment, a fairly robust data set for phosphorus (total and ortho) was available to the SR-HC TMDL effort. The data available for a nitrogen loading assessment was more limited. However, the nitrogen data available show trends similar to those observed for phosphorus within the SR-HC system.

Nutrient data has been collected over the time period from 1975 to current for both the mainstem Snake River and tributary sites. Mean values, concentration ranges and number of data points available are shown in Table 3.2.2 a through c.

Table 3.2.2 a. Distribution of total phosphorus (TP) data available for the Snake River - Hells Canyon TMDL (1975 through 2000).

Sample Site	Number of Samples	Mean TP concentration (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Snake River Inflow (RM 425 to 403)	96	0.081	0.550	0.007
Tributary Mouths				
Owyhee (RM 396.7)	161	0.195	1.46	0.082
Boise (RM 396.4)	255	0.362	2.00	0.07
Malheur (RM 368.5)	80	0.444	1.46	0.06
Payette (RM 365.6)	115	0.101	0.57	0.02
Weiser (RM 351.6)	120	0.172	1.43	0.03
Drains	205	0.340	1.58	0.06
Upstream Snake River Mainstem (RM 409 to 335)	490	0.112	0.885	0.01
Brownlee Reservoir	199	0.110	0.610	0.019
RM 335 to 319		0.148		
RM 320 to 304		0.109		
RM 305 to 285		0.076		
Burnt River (RM 327.5)	92	0.203	2.33	0.081
Powder River (RM 296)	170	0.214	0.694	0.02
Oxbow Reservoir (RM 285 to 272.5)	179	0.087	0.154	0.02
Hells Canyon Reservoir (RM 272.5 to 247)	128	0.083	0.36	0.016
Downstream Snake River Segment (RM 247 to 188)	201	0.079	0.39	0.005

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d and 2000a; USGS, 1999, and Boise City Public Works, 2001.

Table 3.2.2 b. Distribution of dissolved ortho-phosphate (DOP) data available for the Snake River - Hells Canyon TMDL (1975 through 2000).

Sample Site	Number of Samples	Mean DOP concentration (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Snake River Inflow (RM 425 to 403)	22	0.01	0.08	0.001
Tributary Mouths				
Owyhee (RM 396.7)	148	0.070	0.65	0.021
Boise (RM 396.4)	160	0.287	0.58	0.051
Malheur (RM 368.5)	76	0.251	0.39	0.053
Payette (RM 365.6)	103	0.036	0.12	0.005
Weiser (RM 351.6)	13	0.07	0.15	0.02
Drains	nd	nd	nd	nd
Upstream Snake River Mainstem	394	0.027	0.12	0.002
Brownlee Reservoir	184	0.037	0.18	0.005
RM 335 to 319		0.035		
RM 320 to 304		0.034		
RM 305 to 285		0.043		
Burnt River (RM 327.5)	90	0.120	0.40	0.052
Powder River (RM 296)	163	0.149	0.13	0.008
Oxbow Reservoir (RM 285 to 272.5)	179	0.0465	0.13	0.005
Hells Canyon Reservoir (RM 272.5 to 247)	125	0.0426	0.16	0.005
Downstream Snake River Segment (RM 247 to 188)	109	0.054	0.11	0.004

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d and 2000a; USGS, 1999, and Boise City Public Works, 2001. (nd = no data available)

Data has been collected in the form of total phosphorus, ortho-phosphate, and numerous other unique analytical methodologies. Data sets for total phosphorus (n = 2,494) and dissolved ortho-phosphate (dissolved ortho-phosphate (DOP) concentrations and soluble reactive phosphorus (SRP) data, total n = 1,766) were the most robust and were selected for use with the SR-HC TMDL.

Within the available data set, total phosphorus and chlorophyll *a* concentrations are observed to increase markedly from upstream to downstream within the Upstream Snake River segment (RM 409 to 335) (Figure 3.2.3). The total phosphorus concentration in the Upstream Snake River segment is nearly 40 percent higher than that observed at the inflow to this reach (RM 409). Several tributaries discharge water with notably elevated total phosphorus concentrations in this reach.

Table 3.2.2 c. Distribution of chlorophyll *a* (Chl *a*) data available for the Snake River - Hells Canyon TMDL (1975 through 2000).

Sample Site	Number of Samples	Mean Chl *a* concentration (ug/L)	Maximum (ug/L)	Minimum (ug/L)
Snake River Inflow (RM 413 to 403)	115	20.3	115	0.9
Tributary Mouths				
Owyhee (RM 396.7)	34	6.3	14.6	0.3
Boise (RM 396.4)	8	7.6	38.5	0.8
Malheur (RM 368.5)	52	12.6	56.7	0.8
Payette (RM 365.6)	16	8.8	22.1	0.8
Weiser (RM 351.6)	3	2.8	3.4	2.2
Drains	nd	nd	nd	nd
Upstream Snake River Mainstem	316	30.7	179	1
Brownlee Reservoir	1012	28.4	727	0
RM 335 to 319		56.2	727	19
RM 320 to 304		9.0	19	3
RM 305 to 285		1.3	3	0
Burnt River (RM 327.5)	76	9.2	136	0.5
Powder River (RM 296)	117	8.8	74	0
Oxbow Reservoir (RM 285 to 272.5)	354	6.0	117	0
Hells Canyon Reservoir (RM 272.5 to 247)	425	5.6	65	0
Downstream Snake River Segment (RM 247 to 188)	145	4.4	28	0

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d and 2000a; USGS, 1999, and Boise City Public Works, 2001. (nd = no data available)

These tributary inflows are the primary source of phosphorus enrichment in the SR-HC reach. Average total phosphorus concentrations in the Boise and Malheur rivers are greater than four times the concentration in the inflowing Snake River (at RM 409). Average total phosphorus concentrations measured in agricultural drains discharging to the Snake River are only slightly less, still more than four times greater than the mainstem Snake River. All inflowing tributaries contribute water that is higher in average total phosphorus concentration than the mainstem Snake River at RM 409.

A marked decrease in total phosphorus and chlorophyll *a* concentration is observed between where the Snake River enters Brownlee Reservoir (RM 335) and where it exits Hells Canyon Reservoir (RM 247) as show in Figure 3.2.3. The Hells Canyon Complex acts as a phosphorus sink, reducing the average total phosphorus concentration by approximately 33 percent by the time the Snake exits the complex at Hells Canyon Dam. The majority of concentration decrease occurs in Brownlee Reservoir. The decreasing trend in phosphorus concentration is evident from the inflow at approximately RM 335 to the outlet of the dam at RM 285. The overall concentration decrease within Brownlee Reservoir averages approximately 30 percent. Several differences and similarities are evident in the data displayed in Tables 3.2.2 a through c. The average total phosphorus concentrations and the range of concentration values for the Boise and Malheur rivers, and for the averaged agricultural drains are very closely correlated. This same relationship holds for the Boise and Malheur Rivers for ortho-phosphate concentrations as well. In all cases, the Payette River presents a unique set of characteristics quite unlike any of the other tributary systems to the SR-HC reach.

Similar to total phosphorus, dissolved ortho-phosphate concentrations are observed to increase from upstream to downstream (Figure 3.2.3). The dissolved ortho-phosphate concentration at the downstream end of the Upstream Snake River segment (RM 330 to 335) is higher than that observed at the inflow to this reach (RM 409). Ortho-phosphate concentration is notably influenced by uptake from algal growth within the system however, and therefore is not a conservative constituent. Also similar to total phosphorus, tributary dissolved ortho-phosphate concentrations are notably elevated above those observed in the Snake River inflow (Table 3.2.2 b). Tributary inflows are the primary source of dissolved ortho-phosphate enrichment in the SR-HC reach. Average dissolved ortho-phosphate concentrations in the Boise and Malheur rivers are greater than 25 times the concentration in the inflowing Snake River. Dissolved ortho-phosphate concentrations measured in the other tributaries discharging to the Snake River are lower but still several times greater than the mainstem Snake River. All inflowing tributaries contribute water that is higher in dissolved ortho-phosphate than the mainstem Snake River at RM 409. This enrichment of mainstem waters leads to the potential for greater productivity during the summer season.

An increase in dissolved ortho-phosphate concentration is observed as the Snake River moves through the Hells Canyon Complex. The complex acts as a sink for total phosphorus, but internal processing converts a portion of the sediment and/or biota-related phosphorus to dissolved ortho-phosphate (Figure 3.2.4). (This is also evident in the data displayed in a monthly time step in Figures 2.3.17 and 2.3.18.) The relative proportion of ortho-phosphate increases from upstream to downstream within Brownlee Reservoir. This conversion results in an overall increase from the inflowing concentrations at Farewell Bend (RM 335) of nearly 100 percent by the time the Snake exits the complex at Hells Canyon Dam (RM 247). The majority of concentration increase (74%) occurs in Brownlee Reservoir (0.027 mg/L to 0.047 mg/L). However, this increase in available dissolved ortho-phosphate does not result in an increase in algal growth within the reservoir complex and algal blooms are not observed within Oxbow and Hells Canyon Reservoirs or downstream at the same magnitude or intensity with which they occur in the Upstream Snake River segment (RM 409 to 335).

The relationship of total phosphorus, chlorophyll *a* and total suspended solids within the SR-HC TMDL reach provides understanding of transport and processing mechanisms in the riverine and reservoir sections. Figure 3.2.5 shows total suspended solids concentrations decreasing precipitously at the inflow of Brownlee Reservoir (RM 335 to 330). The decrease in chlorophyll *a* describes a less steeply-sloped curve, indicating that algae are among the lighter sediment particles and are therefore transported farther downstream than the more dense (presumably inorganic) solids, which drop out more abruptly. The data available indicate that sediment in this

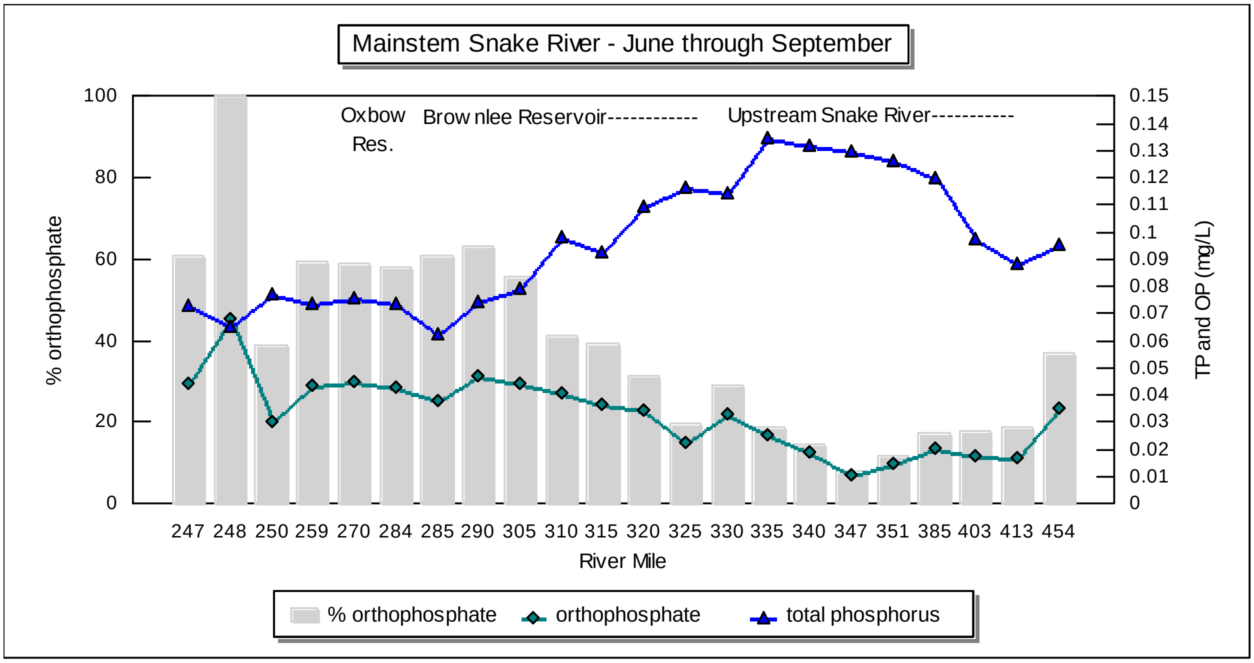


Figure 3.2.4. Spatial distribution of mean phosphorus and chlorophyll *a* concentration data within the Snake River - Hells Canyon TMDL reach (June through September, 1990 to 2000).

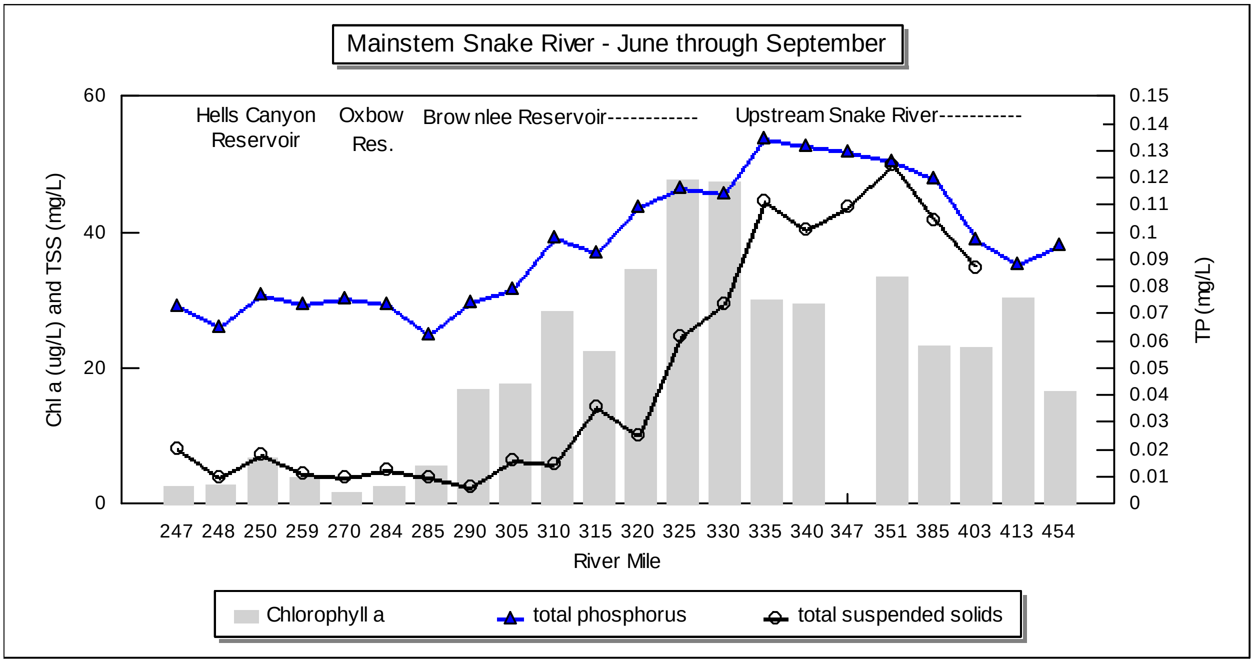


Figure 3.2.5. Spatial distribution of mean total suspended solids, phosphorus and chlorophyll *a* concentration data within the Snake River - Hells Canyon TMDL reach (June through September, 1990 to 2000).

depositional area is predominantly associated with coarser particle sizes, while the smaller, lighter particles are deposited somewhat further downstream.

Total suspended solids concentrations show the most marked decrease between RM 335 and RM 320. Chlorophyll *a* concentrations show the most marked decrease between RM 325 and RM 315. Total phosphorus concentrations show a sustained decrease between RM 335 and RM 285. This indicates that total phosphorus concentrations are the result of both that phosphorus associated directly with the heavier sediment particles (probably inorganic in nature) and that phosphorus originally in the water column that was taken up by algae and incorporated into the biomass moving into the Hells Canyon Complex. A portion of the total phosphorus within the system is also associated with the smaller, lighter inorganic particles (silts and clays) that are transported farther downstream within the system. A portion of this phosphorus, along with that portion associated with the algal biomass is processed within the Hells Canyon Complex and discharged as dissolved ortho-phosphate, as evidenced by the nearly flat curve described by the total phosphorus concentrations in the Oxbow and Hells Canyon Reservoirs.

Chlorophyll *a* concentrations in the inflowing tributaries are relatively moderate, averaging less than 15 ug/L overall. Chlorophyll *a* concentrations are greatest in the Owyhee and Malheur rivers, and least in the Weiser River, but all are relatively low, falling below the action level of 15 ug/L identified by the State of Oregon as a trigger for water quality investigations. All inflowing tributary waters are lower in chlorophyll *a* concentration than the average concentration in the Upstream Snake River segment (RM 409 to 335).

Chlorophyll *a* concentrations were used in this load assessment as a measurement of algae production. The data presented in Table 3.2.2 c show that both the Snake River and the reservoir complex provide an environment suitable for the high levels of algal production. Algal dynamics investigated by IPCo (1998a and 1998b) identified blooms in the lower section of the Upstream Snake River segment (RM 409 to 335) and in the upstream portion of Brownlee Reservoir. Blooms occurred in early May and late June. Concurrent nutrient monitoring indicated that during these blooms, phosphorus was the limiting factor to algal growth. A significant die-off was observed in this study between the two blooms, occurring in mid-May. This trend has been documented to occur with slight variations for a number of years.

The identification of algal populations in major blooms contributing to poor water quality is critical in defining appropriate targets for this TMDL. Several studies have been undertaken to identify algal species in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285). According to work done by Falter in 1999 (reported in IPCo, 1999d), diatoms are the dominant population in the spring and fall in the Snake River. Both green and blue-green algae species are present in the summer.

Algae blooms in the SR-HC reach are observed to be inversely correlated with dissolved ortho-phosphate concentration. During periods of high productivity, chlorophyll *a* concentrations increase while dissolved ortho-phosphate concentrations drop precipitously. With die-off or drop in productivity, dissolved ortho-phosphate concentrations increase, due in part to both lack of uptake and release of dissolved ortho-phosphate from dead and decaying algal materials.

Figure 3.2.6 shows the cyclic relationship observed between chlorophyll *a* and dissolved ortho-phosphate during the course of this bloom.

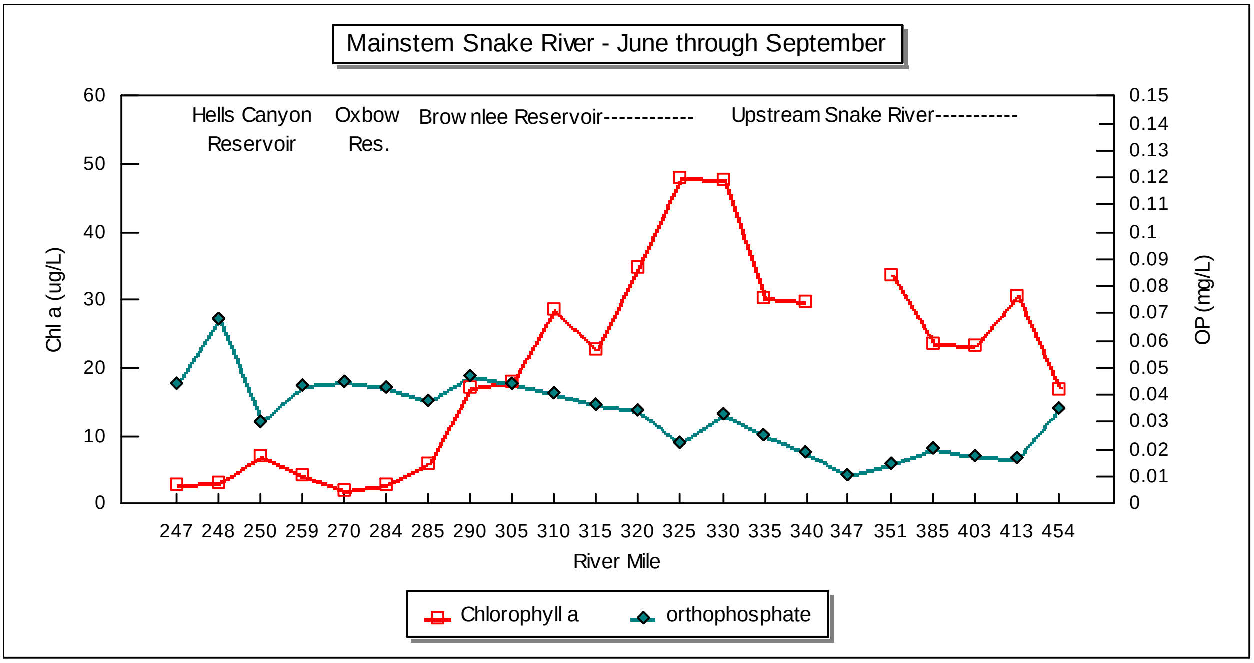


Figure 3.2.6. Algae mass (chlorophyll *a*) vs. dissolved phosphorus concentration for the mainstem Snake River in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285).

The plotted data show relatively low ortho-phosphate concentrations throughout the sections of the SR-HC TMDL reach where chlorophyll *a* concentrations are high. When chlorophyll *a* concentrations start to decrease however, ortho-phosphate concentrations increase. Where chlorophyll *a* concentrations are elevated, a general decrease is observed in the ortho-phosphate concentration.

Relatively low levels of algal production (as identified by chlorophyll *a* measurements) occur in the segment of the Snake River upstream of RM 396. Total phosphorus concentrations in the area of Celebration Park (RM 449) and Adrian, Oregon (RM 403) average approximately 0.08 mg/L over the years for which data are available.

Relatively low levels of chlorophyll *a* are observed in this location, indicating low algal populations in the water column. A visual inspection of the water at Celebration Park shows relatively clear, transparent conditions throughout the summer season, even when the river downstream supports a large algal population.

Several studies of the trophic status of the reservoir complex have been completed (IDEQ, 1993b; IPCo, 1999d), and the reservoirs were identified as being eutrophic. Mechanisms for the determination of trophic status range from relatively simple classifications based on nutrient concentrations to very complex classifications based on a number of interrelated variables. A moderately simple scheme of classification developed by Horne and Goldman (1994) includes four basic characteristics: concentration and supply rates of nutrients, substantial variation in oxygen saturation (supersaturation in the epilimnion and depression of dissolved oxygen concentrations in the hypolimnion), high primary productivity, and cloudy water with relatively low light penetration (Secchi depths 0.1 to 2 m).

Low dissolved oxygen concentrations in the water column have not been documented in the Upstream Snake River segment (RM 409 to 335). During the summer months when low dissolved oxygen concentrations are most likely to occur in areas of slow flow, high algal productivity results in supersaturation of the water column. While low dissolved oxygen is not expected to occur in the river to the degree that it does in the reservoir, due to mixing and shallow water aeration, it is expected that low dissolved oxygen concentrations would occur in areas of slow flow or in places where eddies and backwaters result in sluggish waters, and as a result of diurnal variations in the immediate vicinity of large algal blooms during periods when photosynthesis is not occurring.

As discussed in Section 3.2.2.3, violations of the dissolved oxygen criteria have been documented in data from artificial redd studies conducted upstream of RM 409 by IPCo in 1999 to 2000 and 2000 to 2001 (IPCo, 2001c). These data show dissolved oxygen concentrations of less than 2.0 mg/L during the late spring and summer months at the sediment/water interface between Swan Falls and the upstream portion of the SR-HC TMDL reach. Due to the fact conditions similar to those that occur in the region between Swan Falls and RM 409, also occur in the Upstream Snake River segment (RM 409 to 335), low dissolved oxygen concentrations are likely to occur in areas of the Upstream Snake River segment. Data available on white sturgeon in the Upstream Snake River segment (RM 409 to 335) show that this population is not being supported. Water quality degradation, including low dissolved oxygen at the sediment/water interface is most likely contributing to this lack of support.

3.2.6 Determination of Nutrient Loading

The method used for determination of nutrient loading for the SR-HC TMDL reach is discussed in the general hydrology and loading analysis, and in the sections above.

The available data show that total phosphorus loading into the SR-HC reach originates almost exclusively from the Upstream Snake River segment (RM 409 to 335).

No point source discharge permits in the SR-HC TMDL reach contain phosphorus limitations. One treated wastewater discharger currently monitors for total phosphorus concentrations on a quarterly basis (City of Fruitland). One industrial point source discharger currently monitors for total phosphorus concentrations (Heinz Frozen Foods). The reported concentrations from these monitoring efforts, and estimates available for average discharge concentrations are above the 0.070 mg/L instream target for the SR-HC TMDL. Using available data and estimated discharge concentrations for wastewater treatment plants of 3.5 mg/L, the total phosphorus loading from point source discharges was calculated at 516 kg/year. For facilities discharging part time, only that time when discharge occurred was assessed. Therefore, the calculated point source load for the summer growing season does not include loading from the City of Ontario as this facility utilizes land application in the summer and there is no discharge during the critical period. Point source loading represents approximately 8 percent of the total calculated load to the SR-HC reach. As all point sources discharging directly to the SR-HC TMDL reach do not monitor total phosphorus discharge concentrations, additional data would be necessary to determine actual total phosphorus loading from each permitted point source discharge and the concentration observed at the edge of the mixing zone.

Measured tributary total phosphorus loading to this segment accounts for the majority of the phosphorus load to the SR-HC TMDL reach (76%), with ungaged (estimated) drain flows accounting for 10 percent of the total system load and unmeasured sources accounting for approximately 6 percent of the total. Measured tributary dissolved ortho-phosphate loading to this segment also accounts for the majority of the dissolved ortho-phosphate load to the SR-HC reach (approximately 80%), with ungaged (estimated) drain flows accounting for approximately 7 percent of the total system load and unmeasured sources accounting for approximately 4 percent of the total. Care should be taken in the interpretation of dissolved ortho-phosphate values however, as ortho-phosphate is not a conservative parameter throughout the system.

Sources of unmeasured load may include nonpoint source runoff from anthropogenic sources, precipitation events, unidentified small tributaries and drains, ground-water sources and ground-water sources. As ungaged flows were calculated by subtraction, this may also include error in gaged flow measurements.

Nutrient loads from agricultural drains discharging to the SR-HC reach were determined using concentration and flow data where available. Flow data was not plentiful however, and most flows were estimated using general descriptions and the calculated return flow information by area supplied by the USBR (USBR, 2001). Calculated averages were used in place of concentration values where data were not available. These values therefore should be viewed as best estimates. If additional, drain-specific data become available during the implementation of this TMDL, it will be used in place of these estimates. Land area associated with the drains was calculated at 249,100 acres total (USBR, 2001). A listing of drain names and locations is included in Appendix J.

The relative nutrient loads shown in Table 3.2.3 a and b are calculated for the SR-HC reach using average summer flows (Table 2.1.1).

3.2.7 TMDL Determination

Nutrient standards for both the State of Idaho and the State of Oregon are narrative in nature, identifying that nutrient concentrations that result in the impairment of designated beneficial uses or the production of visible slime growths or other nuisance aquatic growths that impair designated beneficial uses are in violation of the standard.

Given the water quality concerns that can result from excessive nutrient concentrations and the range of concentrations and related system characteristics such as flow, temperature, water column mixing, light penetration and water depth under which these conditions can occur throughout the Pacific Northwest, a narrative nutrient standard is appropriate. Interpretation of

Table 3.2.3 a. Relative point source total phosphorus loads calculated for the Snake River - Hells Canyon TMDL (May through September, 1995, 2000).

Waste Load Type	Location	Design Flow Load (kg/day)	NPDES[1] or other Permit Number
City of Nyssa	RM 385	11	101943 OR0022411
Amalgamated Sugar	RM 385	50	101174 OR2002526
City of Fruitland	RM 373	5.5	ID0020907
Heinz Frozen Foods	RM 370	412	63810 OR0002402
City of Ontario	RM 369	0[1]	63631 OR0020621
City of Weiser	RM 352	32	ID0020290
City of Weiser	RM 352	5.5	ID0001155
Brownlee Dam (IPCo)	RM 285	Unmeasured, assumed minimal[2]	ID0020907
Oxbow Dam (IPCo)	RM 272.5	Unmeasured, assumed minimal[2]	101275 OR0027286
Hells Canyon Dam (IPCo)	RM 247	Unmeasured, assumed minimal[2]	101287 OR0027278
Total Point Source Loading	SR-HC TMDL reach	516	

[1] None of the summer loading produced by the City of Ontario is discharged to the Snake River as land application is employed during the critical months (May through September).
[2] Facilities sump discharge and turbine cooling water, not a phosphorus or waste treatment source.

the narrative standard on a site-specific basis is necessary to identify targets that will protect all designated beneficial uses within the listed segment. The designated beneficial uses determined to be most at risk from excess nutrients were those associated with recreation, aquatic life and domestic water supply. Therefore, establishment of a nutrient target for the SR-HC TMDL reach had to take into account both the concerns associated with the support of designated beneficial uses and the system characteristics that lead to violation of the standard. The process followed to identify nutrient targets for the SR-HC TMDL had two major goals:

1. To identify targets for nutrient loading such that their attainment would result in full support of designated beneficial uses and achievement of water quality standards.
2. To identify the assimilative capacity of the SR-HC reach.

The first goal is directly related to the establishment of a TMDL for nutrients and associated water quality concerns. The second goal is specific to the development of an accurate and equitable load allocation process. Both goals are discussed in greater detail in the following sections.

Table 3.2.3 b. Relative total phosphorus loads calculated for tributaries and other nonpoint sources (NPS) to the Snake River - Hells Canyon TMDL (May through September, based on concentration data from 1995, 1996 and 2000, and mean flow values).

Load Type	Location	Load (kg/day)	Percent of Total NPS Loading
Snake River Inflow	RM 409	1,912	31.5
Owyhee River	RM 396.7	265	4.4
Boise River	RM 396.4	1,114	18.3
Malheur River	RM 368.5	461	7.6
Payette River	RM 365.6	710	11.7
Weiser River	RM 351.6	392	6.5
Drains	Upstream Snake River Segment	660	10.9
Ungaged flows	Upstream Snake River Segment	385	6.3
Agriculture, Stormwater and Forestry	Upstream Snake River Segment (RM 409 to 335)	Included in the ungaged flow loading	
Nonpoint Source Total for the Upstream Snake River Segment (RM 409 to 335)		5,899	97.1
Burnt River	RM 327.5	52	0.9
Powder River	RM 296	126	2.1
Agriculture, Stormwater and Forestry	Brownlee Reservoir segment (RM 335 to 285)	Cannot be calculated, assumed small	
Nonpoint Source Total for the Brownlee Reservoir Segment (RM 409 to 335)			2.9
Agriculture, Stormwater and Forestry	Oxbow Reservoir segment (RM 285 to 272.5)	Cannot be calculated, assumed small	

* NOTE: The values in this column represent the load in the Snake River or tributary at the end of the listed section. For example, the load listed for Brownlee Reservoir is the load that is passed to Oxbow Reservoir at Brownlee Dam. The load listed for the Owyhee River is the load that is transported to the Snake River at the location where the Owyhee joins the Snake. Data in this table are from US EPA STORET, 1998a; IPCo, 1999d and 2000a; USGS, 1999 and Boise City Public Works, 2001.

3.2.8 Identification of Nutrient Targets

Several different processes for identification of nutrient targets have been outlined in the guidance documents for nutrient criteria recently released by the US EPA (US EPA, 2000d). These documents provide information and strategy for establishing nutrient criteria for both rivers and streams, and lakes and reservoirs. The goal of this process was to identify a numeric nutrient target specific to the support of designated beneficial uses in the SR-HC TMDL reach. These documents provided valuable guidance in the establishment of the target. The numeric target was identified to support the narrative criteria already in place for both states.

A first step undertaken in this process was the identification of limiting factors within the SR-HC TMDL system. Two major indicators of limiting factors were evaluated: Nitrogen to phosphorus ratios and algal population dynamics.

3.2.8.1 NITROGEN TO PHOSPHORUS RATIO.

The nitrogen to phosphorus ratio (N:P ratio) and its correlation with algal growth has been the subject of a large body of research. Freshwater systems tend to be phosphorus limited. A general rule often applied to N:P ratios in freshwater systems is that if the N:P ratio is greater than ten, the limiting agent is phosphorus and excessive algal growth will usually not occur if phosphorus is reduced appropriately. If the N:P ratio is less than ten, the limiting agent is nitrogen and excessive algal growth will usually not occur if nitrogen is reduced appropriately.

This has been applied using both soluble and total nutrient measurements. However, care must be taken in using soluble nutrient measurements during an algal bloom to identify this ratio as soluble nutrient concentrations can drop to nearly unmeasurable levels due to rapid uptake. Differences and errors in analytical procedures are more marked at very low concentrations and thus represent a greater relative error. The threshold of ten is commonly applied, and was selected in this analysis as a cutoff value between limiting agents, however, a range of N:P ratios over which nitrogen and phosphorus may be co-limiting agents has been identified as from 7 to 15 (US EPA, 2000d).

Where N:P ratios greater than 10:1 occur in a freshwater system, incidence of algal blooms will likely be controlled by total phosphorus concentrations. Bloom severity will be in relation to the excess phosphorus available (Schindler, 1978; Jaworski, 1981). Generally, a phosphate concentration of 0.01 mg/l will support plankton, while concentrations of 0.05 to 0.1 mg/l phosphate or higher are likely to result in nuisance blooms (Dunne and Leopold, 1978; US EPA, 1986b), depending on site specific conditions.

The data available to the SR-HC TMDL reach was evaluated on a monthly average basis to determine the nitrogen to phosphorus ratio (Figure 3.2.7 and 3.2.8). Total nitrogen (as N) and total phosphorus (as P) measurements were used. Soluble nitrogen and soluble phosphorus data sets were not as plentiful and did not cover the same time frames as well as the total nutrient data sets. Not all data sets included the same number of data points. Where there was a substantial discrepancy in the number of data points within compared data sets an average monthly value was calculated.

The N:P ratios for RM 385 and RM 351.2 were all greater than ten with the exception of the July average at RM 385. This is a good indication that phosphorus acts as a limiting agent in the Upstream Snake River segment (RM 409 to 335). In the months immediately preceding algae blooms, April and May, the N:P ratios are substantially above the threshold value of ten, and are also above the range (7 to 15) where nitrogen and phosphorus have been observed to act as co-limiting agents. During this time period, phosphorus acts as the limiting agent.

In the SR-HC TMDL reach, and in the Mid-Snake TMDL reach (RM 547), both segments where nutrient TMDLs have been prepared, the N:P ratios are substantially higher than those observed in the Snake River sections in-between (Figure 3.2.8). This may be due to the relative differences in water quality within the Snake River system, but may also be influenced by the differences in timing and total number of data points in each of the available data sets. The data evaluation involved in the CJ Strike (2004) and Mid-Snake Succor (2002) TMDL efforts will be helpful in refining upstream contributions to the SR-HC TMDL effort.

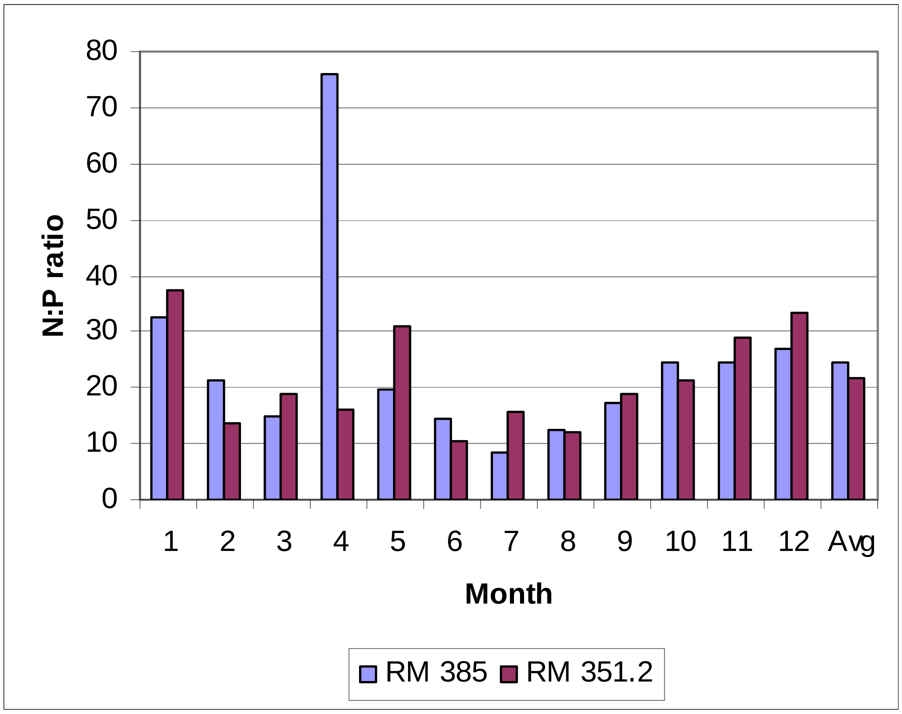


Figure 3.2.7. Nitrogen to phosphorus ratios in the Snake River - Hells Canyon TMDL reach for RM 385 (near Nyssa, Oregon) and RM 351.2 (near Weiser, Idaho).

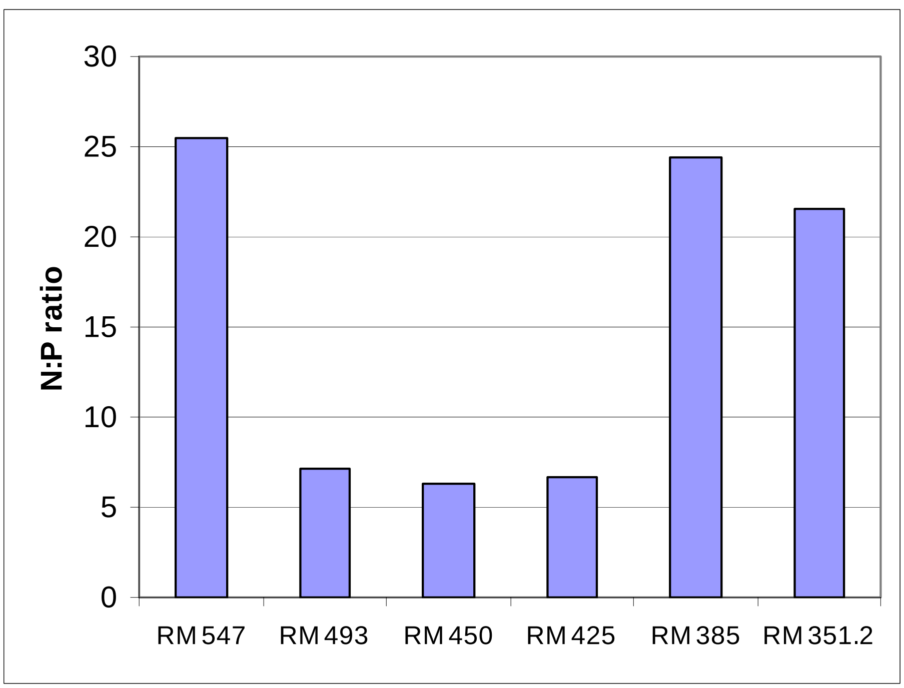


Figure 3.2.8. Nitrogen to phosphorus ratios for different segments of the Snake River. River mile 547 and river mile 385 to 351.2 have been identified as impaired due to excessive nutrient loading on the Idaho State 303(d) list for 1998.

3.2.8.2 Algal Populations.

The identification of algal taxa in major blooms contributing to poor water quality is critical to the identification of limiting agents. The work above shows that throughout the year, phosphorus is the limiting agent in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. During the months of June and August the N:P ratios near the lower end of the Upstream Snake River segment are within the range where nitrogen and phosphorus have been observed to act as co-limiting agents (based on N:P ratios). An identification of the different populations of observed growth in the river is necessary in order to determine with more specificity which nutrient acts as the limiting agent during these time periods.

Several studies have been undertaken to identify algal species in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285). According to work done by Falter in 1999 (reported in IPCo, 1999d), diatoms are the dominant population in the spring and fall in the Upstream Snake River segment (RM 409 to 335). Green and blue-green algae species are present in the summer. Blue-green species dominate where excessive blooms have been identified.

Data collected during a major algal bloom in 1992 in the Snake River between RM 396 and RM 310 showed that the major types of algae present in the Upstream Snake River segment (RM 409 to 335) were cyanobacteria species (*Microcystis aeruginosa*, and *Aphanizomenon flos-aquae*). The algal population in the lower sections of the river were almost exclusively *Anabaena spiroides* (99%), also a cyanobacteria (IDEQ, 1992 to 1993, unpublished data).

A similar study conducted by IPCo in the reservoir complex in 1991, 1993 and 1994 (relatively low flow years) showed the upper end of Brownlee Reservoir dominated by green algae. The middle segment of Brownlee Reservoir showed a mixture of blue-green and green species. Phytoplankton species in the lower segment of Brownlee Reservoir, and the Oxbow and Hells Canyon reservoirs were dominated by cyanobacteria species (IPCo, 1999c).

This information indicates that cyanobacteria species are prominent population types in major algae blooms in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Some cyanobacteria are able to fix nitrogen out of the water both within the water column and at the air/water interface and are therefore difficult if not impossible to control with nitrogen reductions. Phosphorus is therefore the limiting factor in these blooms. Based on this analysis, targets for the SR-HC TMDL reach identify water column concentrations of phosphorus rather than nitrogen. Reductions of phosphorus will likely have the most benefit in reducing blooms composed of these algal species.

3.2.8.3 Target Determination – Scope and Reasoning.

The reasoning behind the determination of a phosphorus target for the SR-HC TMDL reach is outlined in the following sections. This determination was made based on the requirements of the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach.

The SR-HC TMDL is a complex system including both river and reservoir segments. In order to determine the assimilative capacity of the SR-HC TMDL reach, the system was divided into manageable sections. The Upstream Snake River segment (RM 409 to 335) represents the dominant inflow to the Hells Canyon Complex reservoirs and the Downstream Snake River segment (RM 247 to 188). If the Upstream Snake River segment (RM 409 to 335) meets water quality standards in river, the water quality in Brownlee Reservoir will be improved. Only that portion of water quality impairment directly attributable to the reservoir systems, and independent of the inflowing water quality, can be identified as the responsibility of the construction and operation of the reservoirs. Therefore, determination of water quality needs in the Upstream Snake River segment (RM 409 to 335) separate from the Hells Canyon Complex segments is critical to the equitable allocation of load and responsibility within the SR-HC TMDL reach.

The identification of the phosphorus target described in the following sections is based on the needs of the Upstream Snake River segment (RM 409 to 335). The additional needs of the reservoir segments are addressed in the allocation of dissolved oxygen improvements discussed in the sections following the target determination discussion. While upstream water quality is not the sole source of water quality exceedences downstream, it is the dominant source of pollutant loading to downstream segments. (Over 95% of the total phosphorus loading to the SR-HC TMDL reach is delivered by the Upstream Snake River segment (RM 409 to 335)). Therefore, improvements in water quality in the Upstream Snake River segment will result in improvements throughout the SR-HC TMDL reach just as degraded water quality in the Upstream Snake River segment now results in degraded water quality downstream.

3.2.8.4 DEFINITION OF REFERENCE CONDITIONS.

A definition of reference conditions for determination of appropriate nutrient targets for the SR-HC TMDL was undertaken as part of this TMDL process. In the US EPA nutrient guidance document (US EPA, 2000d) the use of reference reaches is discussed as a mechanism to determine appropriate nutrient criteria. This same approach was utilized in the identification of nutrient targets for the SR-HC TMDL. The size, complexity and use-patterns of the Snake River preclude the use of a reference system to determine appropriate phosphorus targets for the SR-HC TMDL reach.

Data available to this assessment included total phosphorus, dissolved ortho-phosphate, total nitrogen and chlorophyll *a* concentrations from 1975 to 2000. A fairly even distribution of spring and summer conditions in high, medium and low water years were available within this data set. Initially, a database of nutrient and chlorophyll *a* information was assembled for various segments of the Snake River. These sections were selected for climate and flow conditions similar to those observed in the SR-HC TMDL reach. The assessment included three general sections of the Snake River: the mainstem above RM 600, the mainstem between RM 400 and 600, and the mainstem between RM 400 and 335. All of these sections are listed as impaired to some degree. No portion of the Snake River mainstem, where characteristics are similar to those observed in the SR-HC TMDL reach, is identified as un-impaired, therefore no true reference condition exists within the mainstem Snake River.

The mainstem Snake River above RM 600 is a section of the river well upstream of the SR-HC TMDL reach. Some reaches of this section are listed in the State of Idaho 1998 303(d) list as being impaired due to excess sediment (HUC #17040212, #17040209, and #17040206), low dissolved oxygen and excess nutrients (HUC #17040206). For the majority of its length however, this section is not listed for nutrient or dissolved oxygen related concerns. It is therefore, by definition, the “least impaired section” evaluated as part of this assessment.

The mainstem Snake River between RM 400 and 550 is the section of the river immediately upstream of the SR-HC TMDL reach. This section is listed in the State of Idaho 1998 303(d) list as being impaired due to excess sediment and nutrients (HUC #17050101 and part of HUC #17050103), low dissolved oxygen, bacteria, and pH (part of HUC #17050103), and pesticides (HUC #17050101). For the majority of its length this section is listed for nutrient and/or dissolved oxygen related concerns. It is therefore, by definition, “the moderately impaired section” evaluated as part of this assessment.

The mainstem Snake River between RM 400 and 335 is a section of the river included in the Upstream Snake River segment of the SR-HC TMDL reach. This section is listed in the State of Idaho 1998 303(d) list as being impaired due to excess sediment, nutrients, low dissolved oxygen, bacteria, pH (part of HUC #17050103 and HUC #17050115). For the entire length this section is listed for nutrients related concerns. It is therefore, by definition, “the heavily impaired section” evaluated as part of this assessment.

As stated above, data from 1975 to 2000 was utilized in this assessment. Data from single years were not compared to other years; rather, direct correlations between total phosphorus concentrations and chlorophyll *a* concentrations existing within the system at any one time were compared with each other. The identification of the relationship of total phosphorus concentrations to chlorophyll *a* concentrations was the main object of this assessment. Therefore, although the older data may not represent current conditions, they do represent the relationship between total phosphorus and chlorophyll *a* existing within the system at that time.

Many sections of the Snake River where climate and flow conditions were similar to those in the SR-HC TMDL reach did not have data available for use in this TMDL. The sections utilized, therefore, represent those sections where data was available, and where climate and flow conditions are comparable to the SR-HC TMDL reach. It is recognized that the flow volume in portions of the Snake River upstream of the SR-HC TMDL reach is less than the flow volume in the SR-HC TMDL reach, however, this data set represents the best available information and has been used to establish general targets.

A general distribution of concentration values for chlorophyll *a* and total phosphorus is displayed in the box and whisker plots shown in Figures 3.2.9 and 3.2.10. A *box-and-whisker* plot is a visual representation of how data is spread out and how much variation there is within the data set. The “box” shows the data included in the second and third quartiles, with the median marked as a solid line across the box. The “whiskers” show the range of the data (highest and lowest value).

Figure 3.2.9 contains concentration and range information for chlorophyll *a* in the mainstem Snake River. Mean chlorophyll *a* concentrations observed upstream of RM 400 are between 12 ug/L and 15 ug/L. Between RM 350 and 330 a substantial increase is observed to occur, with

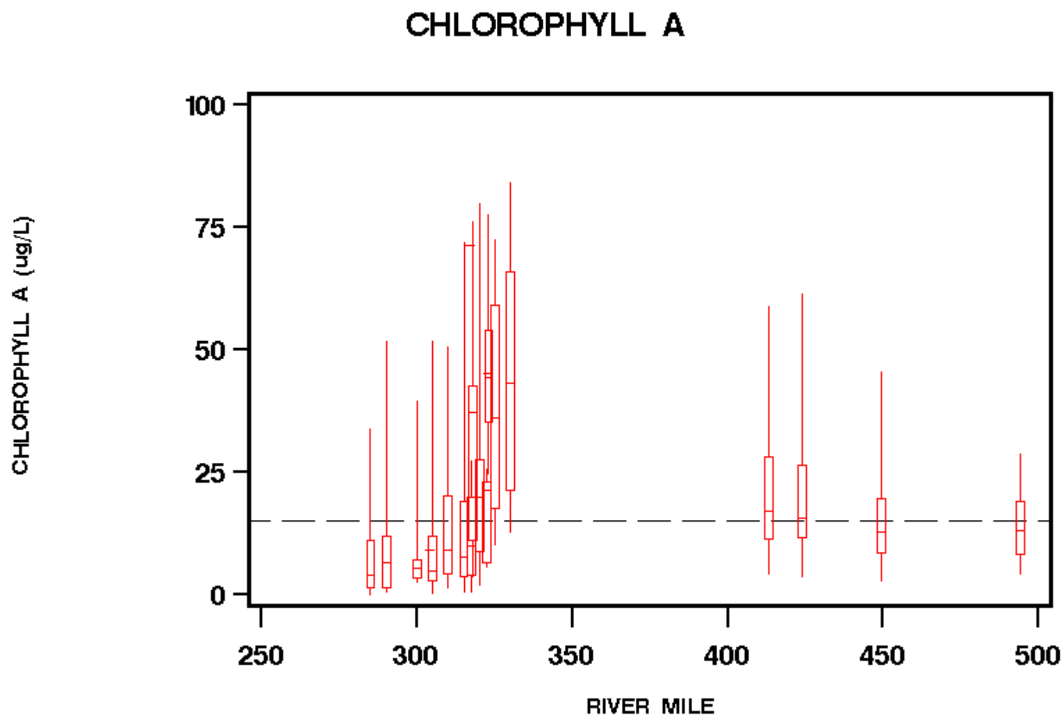


Figure 3.2.9. Box and whisker plot for chlorophyll *a* concentrations within the Snake River system.

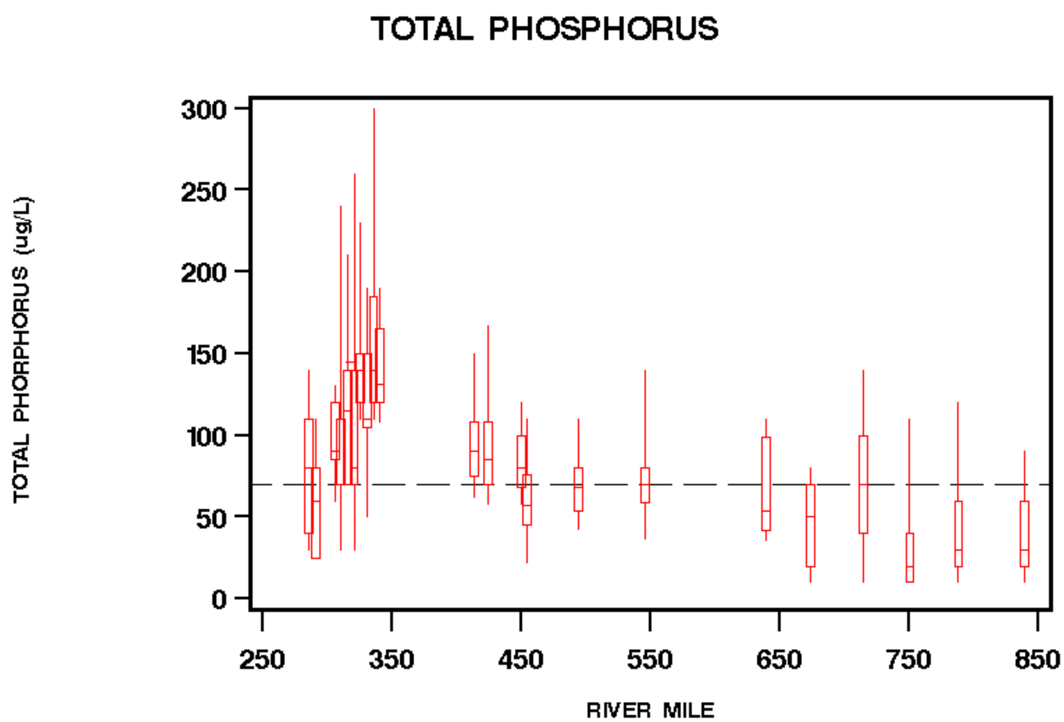


Figure 3.2.10. Box and whisker plot for total phosphorus concentrations within the Snake River system.

mean chlorophyll *a* concentrations between 25 ug/L and 40 ug/L, followed by a substantial decrease downstream of RM 330 (Brownlee Reservoir) to between 7 ug/L and 12 ug/L.

Total phosphorus concentrations displayed in Figure 3.2.10 follow a similar trend. Mean total phosphorus concentrations observed upstream of RM 600 are between 0.03 and 0.07 mg/L. Between RM 400 and RM 600 a slight increase is noted, with mean concentrations between 0.04 and 0.07 mg/L. Between RM 350 and 330 a substantial increase is again observed to occur, with mean total phosphorus concentrations increasing to between 0.09 and 0.14 mg/L, followed by a substantial decrease downstream of RM 330 to approximately 0.06 mg/L.

The concentration data plotted for the Upstream Snake River segment (RM 409 to 335) in Figures 3.2.9 and 3.2.10 show that chlorophyll *a* concentrations observed in the Upstream Snake River segment (RM 409 to 335) are generally 10 ug/L to 15 ug/L higher than those observed in the Snake River upstream of RM 400. Total phosphorus concentrations in this segment are generally 0.05 mg/L to 0.07mg/L higher than those observed in the Snake River upstream of RM 400. This suggests that the Upstream Snake River segment (RM 409 to 335) has a higher loading of both chlorophyll *a* and total phosphorus than the upstream sections of the Snake River as a whole. This relationship is also evident in the data plotted in Figures 3.2.11 and 3.2.12.

Cumulative distribution function (cdf) plots for chlorophyll *a* and total phosphorus for the sections described previously are shown in Figures 3.2.11 and 3.2.12. Cumulative distribution

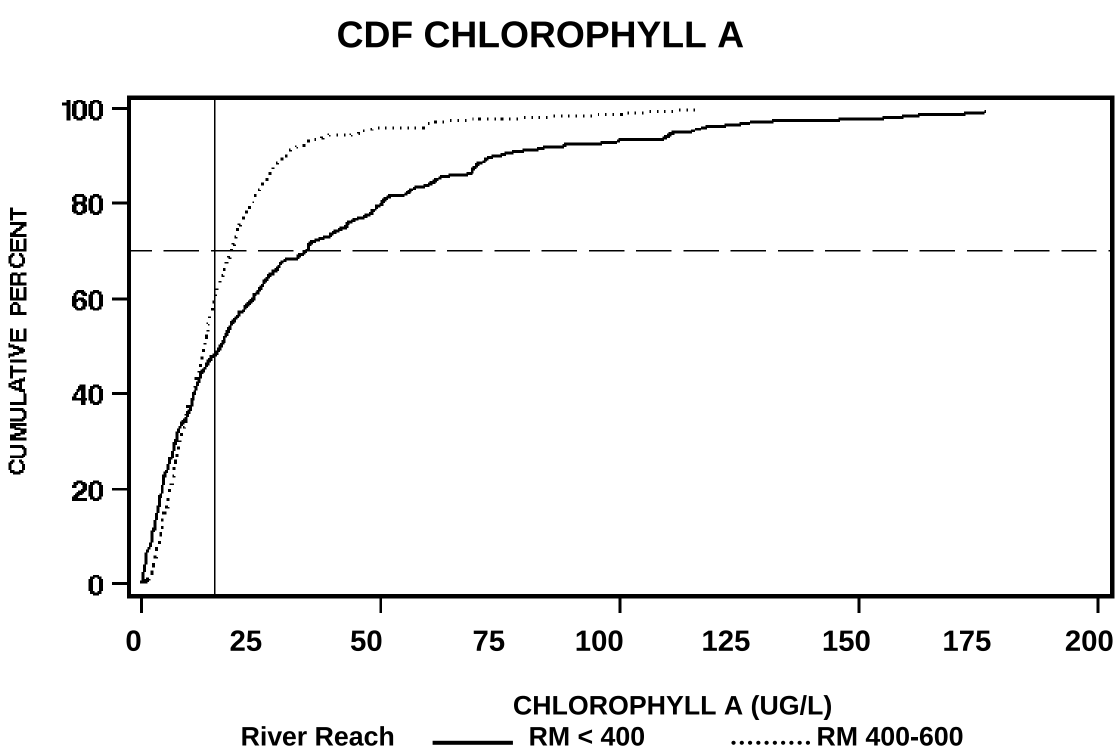


Figure 3.2.11. Cumulative distribution function (cdf) plot of chlorophyll *a* concentrations for two separate sections of the Snake River.

function plots represent the probability that the parameter of concern (in this case the chlorophyll *a* or total phosphorus concentration on the horizontal axis) is less than or equal to a certain percentage (identified on the vertical axis).

The plots for both chlorophyll *a* and total phosphorus show a similar trend in that the downstream section (RM 400 to 335) exhibits notably higher concentrations a greater portion of the time than the upstream sections (RM 400 to 600, or upstream of RM 600). This suggests greater overall loading and greater overall impact to water quality is occurring in the Upstream Snake River segment (RM 409 to 335). For this reason, the Snake River sections upstream of the SR-HC TMDL reach were used in the determination of reference conditions for the SR-HC TMDL reach.

US EPA (2001d) guidance suggests the identification of three concentration ranges based on a frequency distribution as a starting point for determining reference conditions, at risk conditions, and impaired conditions. In order to ensure representative ranges, and minimize the potential that outliers in the data would create a bias, the lowest and highest measured values (5%) were eliminated from consideration. The assessment was accomplished using the data distributed between the 5th and 95th percentiles. This data distribution was then divided evenly into three categories with the 35th percentile concentration defining the threshold below which reference conditions would be defined, and the 65th percentile defining the threshold above which

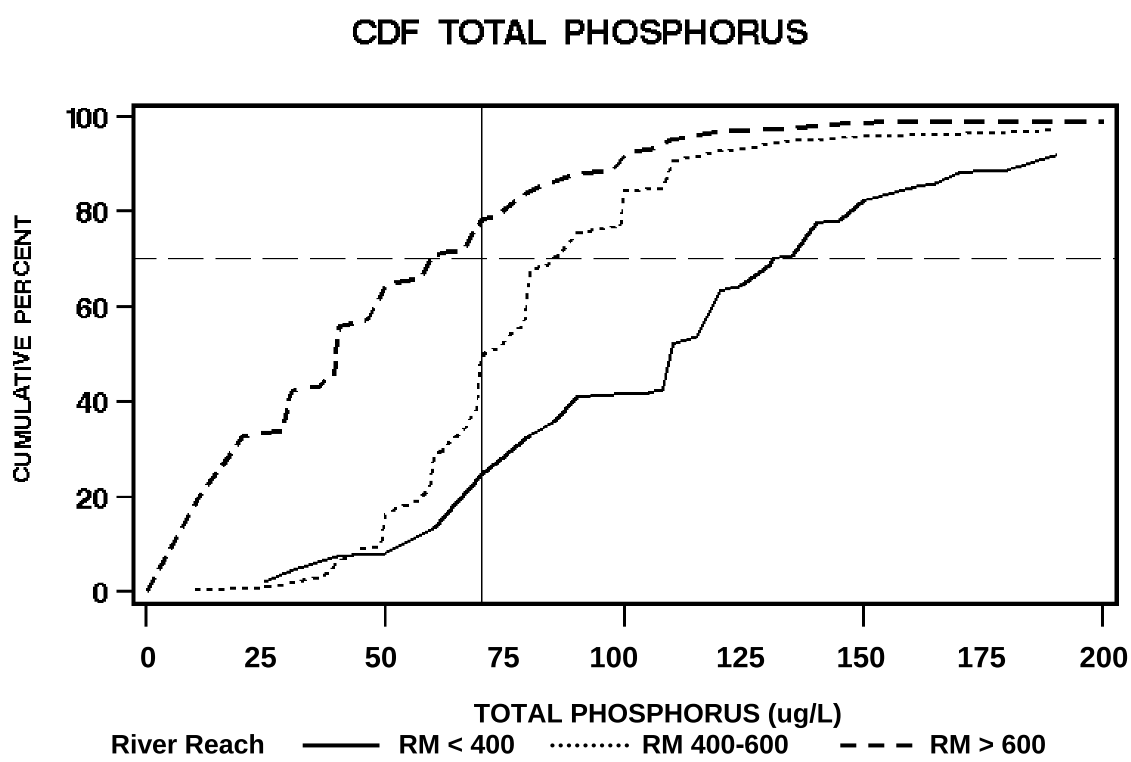


Figure 3.2.12. Cumulative distribution function (cdf) plot of total phosphorus concentrations for three separate sections of the Snake River.

impairment was projected to occur. The concentration range described between the 35th and the 65th percentiles was recommended as a definition of allowable conditions, with lower values tending toward better water quality conditions and higher concentration values being defined as more at risk for impairment. The results of this analysis are tabulated in Table 3.2.4.

Table 3.2.4. Distribution of total phosphorus and chlorophyll *a* data for the Snake River system (1992 through 1995, May through September data).

Data Reach	Data Range	35th Percentile Value	65th Percentile Value
Total Phosphorus (mg/L)			
Snake River System upstream of RM 600	0.01 to 0.28	0.025 mg/L	0.053 mg/l
Snake River between (RM 400 and 600)	0.022 to 0.411	0.065 mg/L	0.077 mg/L
Upstream Snake River segment (RM 409 to 335)	0.01 to 2	0.080 mg/L	0.125 mg/L
Chlorophyll a (ug/L)			
Snake River between (RM 400 and 600)	1 to 115	9 ug/L	16 ug/L
Upstream Snake River segment (RM 409 to 335)	1 to 95	9 ug/L	25 ug/L

Using the general guidance from the US EPA (2000d), the 35th percentile data from the section of the Snake River upstream of RM 600 was used to identify concentration values appropriate to reference conditions for the Snake River system. Using this method, total phosphorus concentrations equal to or less than 0.025 mg/L would represent high quality "reference" conditions. This correlates well with the calculated natural background concentration of 0.02 mg/L based on available data. Applying the 65th percentile concentration value as the threshold concentration above which impairment would be projected to occur would establish an upper concentration limit of 0.053 mg/L for total phosphorus.

The same analysis was performed using the data available from RM 400 to RM 600. Within this data set, total phosphorus concentrations equal to or less than 0.065 mg/L would represent high quality "reference" conditions. Applying the 65th percentile concentration value as the threshold concentration above which impairment would be projected to occur would establish an upper concentration limit of 0.077 mg/L for total phosphorus. This correlates well with the calculated target concentration identified by the Mid-Snake TMDL (IDEQ, 1997c) of 0.075 mg/L for the support of designated beneficial uses and attainment of water quality standards.

To maintain consistency between the total phosphorus and chlorophyll *a* data sets, the 65th percentile values from both the data set collected upstream of RM 600 and the data set from RM 400 to RM 600 were used to establish a range of concentration values (0.053 mg/L to 0.077 mg/L) as a starting point for total phosphorus target determination.

As no chlorophyll *a* data were available from the Snake River upstream of RM 600, data from RM 400 to RM 600 were evaluated using the same methodology to identify preliminary chlorophyll *a* targets for the SR-HC TMDL reach. Based on this analysis, chlorophyll *a* concentrations equal to or less than 9 ug/L would represent high quality "reference" conditions for the SR-HC TMDL, and the threshold concentration above which impairment would be projected to occur would establish an upper concentration limit of 16 ug/L for chlorophyll *a* concentrations in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach.

These values (chlorophyll *a* threshold concentrations of 16 ug/L or less and a total phosphorus threshold target range of 0.053 mg/L to 0.077 mg/L) were used as an initial starting point for identification of targets to attain water quality standards and meet the needs of the designated beneficial uses defined in Section 3.2.2.

Figures 3.2.9 through 3.2.12 and Table 3.2.4 provide evidence that the distribution of chlorophyll *a* and total phosphorus concentrations observed in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach are elevated when compared to those observed upstream of the SR-HC TMDL reach (upstream of RM 409) in the Snake River system.

The 65th percentile value for chlorophyll *a* in the Upstream Snake River segment (RM 409 to 335) is 63 percent higher than the 65th percentile value observed in the Snake River between RM 400 and RM 600. Similarly, the 65th percentile value for total phosphorus observed in the Upstream Snake River segment is 49 percent over the 65th percentile value observed in the Snake River between RM 400 and RM 600. This value is more than two times greater than the 65th percentile value observed in the Snake River upstream of RM 600.

3.2.8.5 CHLOROPHYLL *A* AND TOTAL PHOSPHORUS TARGET IDENTIFICATION.

The statistical determination of reference conditions discussed above supplied a valid range of values for reference and threshold target determination. This range was then related to the unique characteristics of the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach to "ground truth" the general characteristics described by using information specific to this segment and identify a specific numeric target for this reach.

Excessive algal growth is the dominant factor in the impairment of designated beneficial uses in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL. Excessive algal growth has both direct and indirect effects on designated beneficial uses. Direct effects include degradation of aesthetic and recreational opportunities, and the concerns associated with excessive organic loading in domestic water supplies. Indirect effects include low dissolved oxygen resulting from the decomposition of decaying algae, and the associated chemical changes that result. Controlling algal growth in the Upstream Snake River segment (RM 409 to 335) will act to improve water quality and address these impacts to designated beneficial use support.

The identification of a target specific to algal growth or biomass is at best cumbersome and difficult to define. Therefore, chlorophyll *a* (commonly used as a surrogate measure for algae biomass) will be used as a target for the Upstream Snake River segment (RM 409 to 335). The chlorophyll *a* target selected has been identified as appropriate to attain water quality standards and be protective of all designated beneficial uses. Designated beneficial uses in the Upstream Snake River segment that were evaluated in this assessment include: aquatic life, domestic water supply, aesthetics and recreation.

Aquatic life:

As the target identified must be protective of all designated beneficial uses, and as aquatic life uses are generally more sensitive than recreational or aesthetic uses, the support of aquatic species is an important consideration. Mountain whitefish, a salmonid species, are known to inhabit the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. However, this TMDL acknowledges that a mixed fishery is present in this segment, made up of warm, cool and cold water species. A review of existing literature regarding nuisance thresholds and chlorophyll *a* standards by Pilgrim et al. (2001) reported chlorophyll *a* standards for waters likely inhabited by salmonids at 10 to 15 ug/L, and for waters not inhabited by salmonids at 25 to 40 ug/L. The 65th percentile threshold target of 16 ug/L is close to the upper range defined for salmonid-supporting waters and below the range defined for non-salmonid supporting waters.

Domestic water supply:

To be protective of domestic drinking water supplies, Rashke (1994) proposed a mean growing season chlorophyll *a* limit of 15 ug/L for surface water bodies utilized as water supplies. The 65th percentile threshold target of 16 ug/L is close to this limit.

Aesthetics and recreation:

In the acknowledgement that of information specific to the local perception of acceptable chlorophyll *a* concentrations was limited, information available from other studies (discussed in Section 3.2.2.1) was also utilized. This information provides a range of between 15 and 50 ug/L for maximum chlorophyll *a* concentrations for the support of aesthetics and recreation in North America (Table 3.2.1). These values are maximum concentrations; mean concentrations observed would therefore be expected to be lower, depending on the allowable level of exceedence. Additional data on water discoloration (Table 3.2.5) shows that an acceptable level of discoloration commonly occurs at chlorophyll *a* concentrations between 10 and 15 ug/L. Above this, deep discoloration is observed to occur, along with the formation of algal scum. The 65th percentile threshold target of 16 ug/L is within the lower end of the range defined for maximum allowable concentrations, and near the upper end of the range defined for allowable water discoloration.

Table 3.2.5 Water discoloration linked to chlorophyll *a* concentrations for water bodies in the southeastern United States (from Raschke, 1993).

Chlorophyll *a* (ug/L)	Degree of Water Discoloration
> 10	No water discoloration
10 to 15	Some discoloration, some development of algal scums
20 to 30	Deep discoloration, frequent algal scum formation
> 30	Very deep discoloration, intense matting of algal scum

The ranges identified above as being protective of designated beneficial uses extend from 10 ug/L to 50 ug/L. The 16 ug/L target identified previously as the threshold above which impairment is likely to occur falls at the low end of the range presented for protection of aesthetics and recreation. This value is near the high end of the range presented for the protection of salmonids but below the range presented for the protection of non-salmonids. This value is very close to that defined as being protective of domestic water supply uses. Therefore, a chlorophyll *a* target of less than or equal to 16 ug/L mean growing season concentration appears to be protective of the more sensitive designated uses for the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. Because this assessment evaluated the relationship between total phosphorus and chlorophyll *a* throughout the system as a whole, recommended associated error included over/underestimation of overall concentration by grab sampling (10% to 25%), and analytical error (3% to 5%). Error ranges were recommended by Dr. Paul Woods of the USGS (sample error) and certified federal and state analytical laboratories (analytical error). Sampling and analytical protocol information is available for USGS, US EPA, and IPCo data utilized in this assessment. These data represent the primary data sources for this evaluation. As all sample collection and analytical work for these data were performed under rigorous, well defined protocols, conservative error estimates were used for all sources. This resulted in an overall MOS of 13 percent. Applying this MOS to the initial 16 ug/L threshold value yields a target of 14 ug/L chlorophyll *a*.

The allowable level of exceedence for this target is recognized as critical factor in the support of designated beneficial uses. Frequency exceedence levels of up to 25 percent were found to be protective for recreational uses by Smeltzer and Heiskary (1990) and have been applied in this assessment. Given the existing data set, based on summer growing season chlorophyll *a* concentrations, this exceedence level, combined with the 14 ug/L mean growing season concentration target results in a nuisance threshold of 30 ug/L chlorophyll *a*.

A 14 ug/L mean growing season chlorophyll *a* concentration and a nuisance threshold of 30 ug/L chlorophyll *a* is projected to be protective of all designated beneficial uses, and to result in the attainment of appropriate water quality within the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach, it has been established as the chlorophyll *a* target for this TMDL.

In order to attain the chlorophyll *a* target identified for the Upstream Snake River segment of the SR-HC TMDL reach, reductions in total phosphorus concentrations in the mainstem Snake River must be accomplished. In a ranked, paired distribution of data (Figure 3.2.13 a), the nuisance threshold of 30 ug/L chlorophyll *a*, combined with the 14 ug/L mean growing season concentration target corresponds to total phosphorus concentrations between 0.053 mg/L and 0.077 mg/L. In order to define the appropriate numeric total phosphorus target for the Upstream Snake River segment (RM 409 to 335), several issues were considered.

An inflection point is apparent in the plotted data (Figure 3.2.13a), occurring between 0.065 and 0.072 mg/L total phosphorus. The difference in trend between total phosphorus concentrations below 0.065 mg/L and concentrations above 0.072 mg/L indicates that greater chlorophyll *a* concentrations (and therefore greater total biomass) occur at higher concentrations of total phosphorus. This correlation is somewhat intuitive, but variation in natural systems often makes it difficult to define quantitatively.

While the chlorophyll *a* values at and below the inflection point in Figure 3.2.13 a are very similar, chlorophyll *a* concentrations associated with total phosphorus concentrations greater than 0.072 mg/L, especially maximum concentrations, are substantially greater than those associated with total phosphorus concentrations less than 0.072 mg/L. As shown in Table 3.2.6,

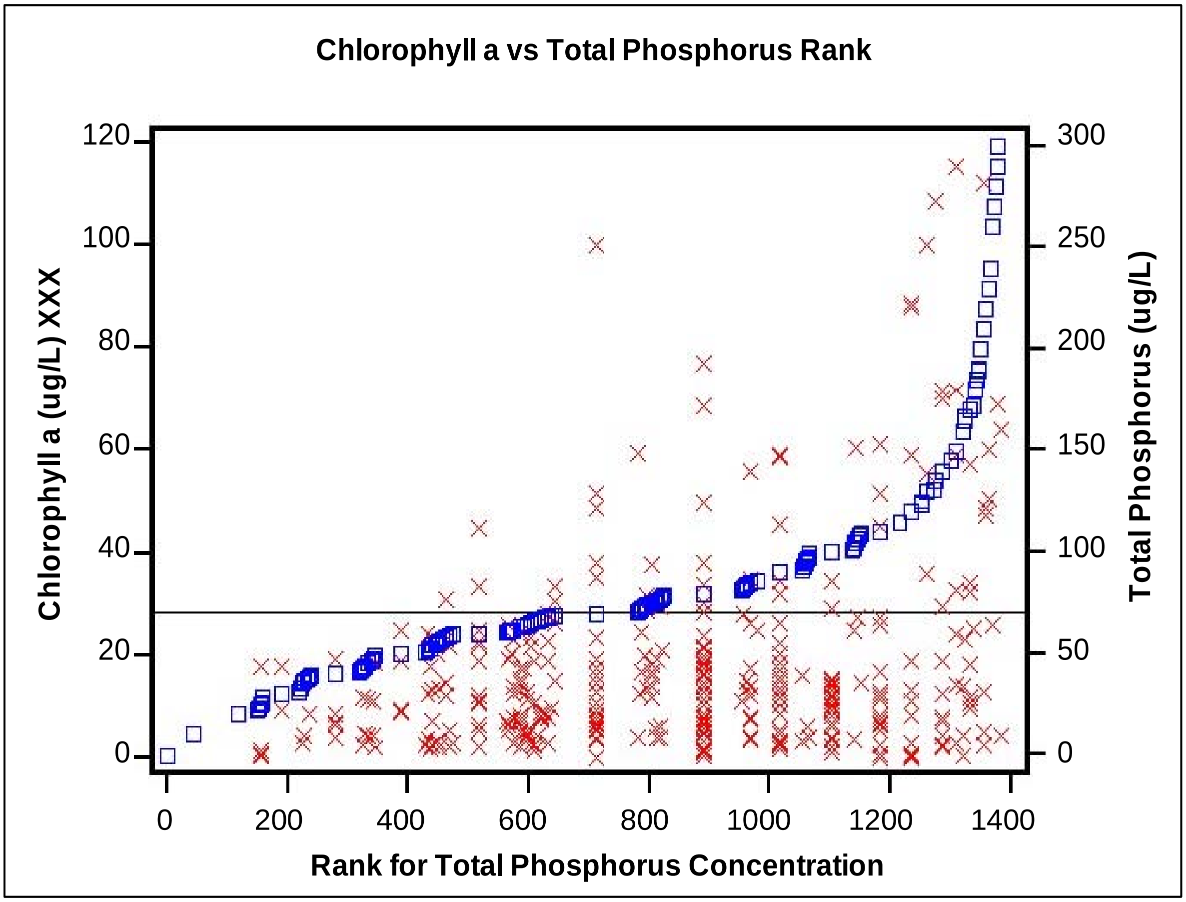


Figure 3.2.13 a. Chlorophyll *a* concentration data as correlated with increasing total phosphorus concentration for the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL.

Table 3.2.6. Correlated total phosphorus and chlorophyll *a* values for Upstream Snake River segment (RM 409 to 335) data.

Total Phosphorus Range	Chlorophyll *a* Range	Chlorophyll *a* mean	Chlorophyll *a* 65th Percentile
0.01 mg/L to 0.065 mg/L	0 ug/L to 44 ug/L	11.8 ug/L	14.6 ug/L
0.065 mg/L to 0.072 mg/L	0 ug/L to 45 ug/L	11.8 ug/L	16.0 ug/L
0.072 mg/L to 2.0 mg/L	0 ug/L to 95 ug/L	24.8 ug/L	30.8 ug/L

the maximum, average chlorophyll *a* values associated with total phosphorus concentrations greater than 0.072 mg/L are double those observed at or below this value. When these values are compared to those observed in the analysis of the larger Snake River system data set, upstream of RM 400, they supply additional information on water quality improvements. The total phosphorus concentrations at the inflection point are within the range described by the previous analysis of the Snake River data, namely 0.053 mg/L to 0.077 mg/L. Additionally, these data show that measurable reductions in algal biomass can be achieved by attaining the 0.072 to 0.065

mg/L concentration, but that reductions below 0.065 mg/L will probably not result in substantially greater improvements than those achieved at 0.065 mg/L. This is important in the consideration of the economic costs of implementation. For this reason, the lower threshold value identified by the data set from upstream of RM 600 (0.053 mg/L) was considered inappropriate to the SR-HC TMDL reach and will not be applied.

The remaining threshold value (0.077 mg/L) was assessed using best professional judgement and estimates of associated error. Because this assessment evaluated the relationship between total phosphorus and chlorophyll *a* throughout the system as a whole, recommended associated error included over/underestimation of overall concentration by grab sampling (10% to 25%), and analytical error (3% to 5%). Error ranges were recommended by Dr. Paul Woods of the USGS (sample error) and certified federal and state analytical laboratories (analytical error). Sampling and analytical protocol information is available for USGS, US EPA, and IPCo data utilized in this assessment. These data represent the primary data sources for this evaluation. As all sample collection and analytical work for these data were performed under rigorous, well defined protocols, conservative error estimates were used for all sources. This resulted in an overall margin of safety of 13 percent. When applied to the threshold values generated by the data set from RM 400 to RM 600 (0.077 mg/L total phosphorus), a target value of 0.067 mg/L total phosphorus was identified, 0.07 mg/L (after rounding). These target concentrations were then evaluated for designated use support within the SR-HC TMDL reach.

3.2.8.6 Target Evaluation for Designated Use Support.

Within the ranked data set it was observed that a general increasing trend in maximum chlorophyll *a* concentration occurred with increasing total phosphorus concentration (Figure 3.2.13a). Although there is variation within the data set, a general correlation of increasing maximum chlorophyll *a* values with increasing total phosphorus concentration was observed in the data.

The target of 0.07 mg/L total P (over the growing season) is projected to result in a median chlorophyll *a* concentration of about 12 ug/L (Figure 3.2.13 a). When median total P concentrations are at 0.07 mg/L, maximum chlorophyll *a* concentrations rarely exceed 30 ug/L in this system (this is because to a first approximation about one-half of the total P in a system is available to the algae). Therefore maximum total P concentrations of 0.07 mg/L will result in substantially lower median seasonal chlorophyll *a* concentrations, probably around 15 ug/L.

This is corroborated when comparing the Snake to other lakes and reservoirs in the Pacific Northwest (Figure 3.2.13 b). Median total P concentrations during the growing season below 0.07 mg/L typically produce median chlorophyll *a* concentrations less than 15 ug/L. If the target of 0.07 mg/L total P in the Snake is realized, median total P will be much less than 0.07 mg/L and the chlorophyll *a* concentrations correspondingly lower. Thus the “average” of 14 ug/L chlorophyll *a* corresponding to a maximum total P of 0.07 mg/L appears to be reasonable. Moreover, the 0.07 mg/L target will eliminate the large peaks in chlorophyll *a* observed in the upper part of the reservoir (Figure 3.2.13 a).

Chlorophyll *a* concentrations correlated with total phosphorus concentrations between 0.02 mg/L and 0.065 mg/L ranged from a minimum of 0 ug/L to a maximum of 44 ug/L (Table 3.2.6). The average chlorophyll *a* concentration over this range was 11.8 ug/L. Chlorophyll *a* concentrations correlated with total phosphorus concentrations between 0.065 mg/L and 0.072 mg/L, ranged from a minimum of 0 ug/L to a maximum of 45 ug/L. The average chlorophyll *a* concentration over this range was 11.8 ug/L. Chlorophyll *a* concentrations correlated with total phosphorus concentrations above 0.072 mg/L ranged from a minimum of 0 ug/L to a maximum of 95 ug/L. The average chlorophyll *a* concentration over this range was 24.8 ug/L.

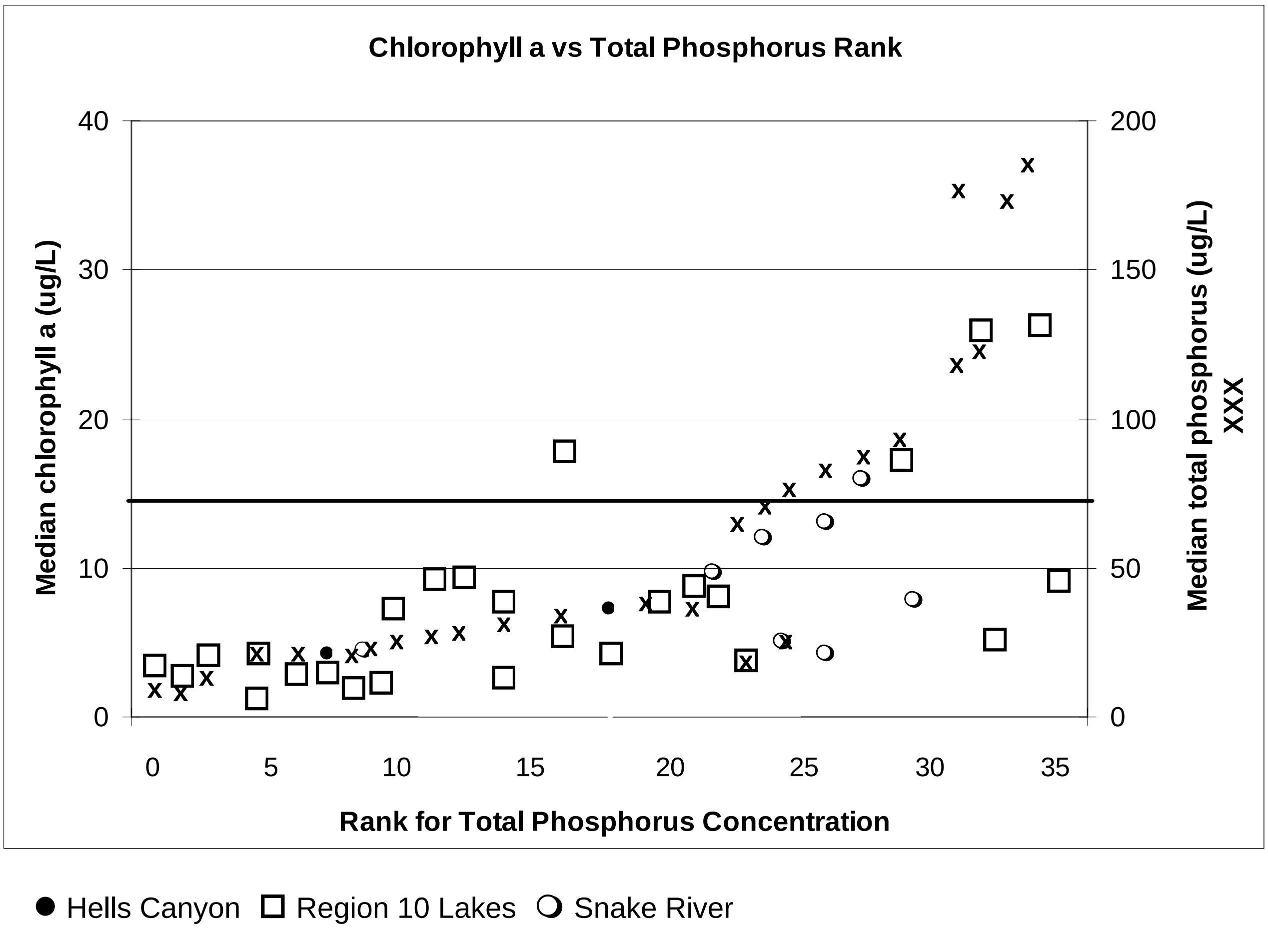


Figure 3.2.13 b. Comparison of median chlorophyll *a* concentration data as correlated with median total phosphorus concentration data for lakes and reservoirs in the Pacific Northwest.

If the 14 ug/L mean growing season chlorophyll *a* target is achieved through attainment of the 0.07 mg/L total phosphorus target, then designated beneficial uses in the Upstream Snake River segment (RM 409 to 335) directly linked to algal growth will be supported. These include domestic water supply, aesthetics and recreation. Full support of the aquatic life designated beneficial uses is dependent on the level of improvement in dissolved oxygen that occurs as a result of reduced algal growth. While algal blooms are expected to occur even with attainment of the 0.07 mg/L total phosphorus target, the frequency of occurrence will be reduced and the peak chlorophyll *a* concentrations should generally remain less than 30 ug/L. This is projected to result in full support of aesthetics and recreational designated beneficial uses and improved dissolved oxygen concentrations.

Attainment of the 0.07 mg/L target value represents a substantial reduction in the current average total phosphorus concentration in the SR-HC TMDL reach. Mainstem total phosphorus concentrations in the Snake River near Weiser average 0.13 mg/L to 0.14 mg/L total phosphorus annually (1999 to 2000 data set). The 0.07 mg/L target will require an overall reduction of 54 percent in total phosphorus concentration in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. When natural loading is accounted for (0.02 mg/L) the anthropogenic-related concentration is calculated at 0.11 mg/L to 0.12 mg/L. Using this concentration, to decrease total phosphorus concentration to 0.07 mg/L will require a 62 percent reduction in overall anthropogenic loading.

Attainment of the 14 ug/L mean growing season chlorophyll *a* target represents a reduction of roughly 44 percent in chlorophyll *a* and associated algal biomass. Approximately 1.5 percent of algal organic matter is chlorophyll *a* (Raschke, 1993). The average chlorophyll *a* concentration in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach during the summer season is 24.8 ug/L (103 ug/L maximum). Translated to algal biomass using the relationship above, in conjunction with 1995 (July average) flows at the Weiser gage of 15,000 cfs, this represents an algal biomass loading of approximately 61,000 kg/day (67 tons/day) near the Weiser gage station in the mainstem Snake River.

The average calculated chlorophyll *a* concentration resulting from attainment of the 0.07 mg/L total phosphorus target is 14 ug/L. This translates to an algal biomass loading of approximately 34,000 kg/day (37 tons/day) near the Weiser gage station. The reduction realized in total algal biomass is 27,000 kg/day (30 tons/day). This calculation does not account for additional reductions in biomass (periphyton and other organic growth) that can be directly influenced by reductions in nutrient concentrations.

In order to evaluate the influence of this reduced biomass on dissolved oxygen in the downstream river and reservoirs, several assumptions were made. It was assumed that the algae-related organic material was 50 percent labile (easily decomposed) and 50 percent refractory (more stable). It was also assumed that the decay of the labile fraction would occur in a day's time. Both of these assumptions are somewhat conservative, but still allow a relative evaluation of the influence of reduced organic loading to the system. Using a conservative organic matter/O_2 demand coefficient of 0.8 (Newbold and Liggett, 1974; Cole and Buchak, 1995), the reduction in organic matter from the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets results in a savings of 16,500 kg/day (18.2 tons/day) of oxygen in the water column. This equates to an approximately 0.3 mg/L dissolved oxygen increase in the water column as a whole or, perhaps more appropriately, 2 mg/L improvement in dissolved oxygen in 20 percent of the water column (improvements in dissolved oxygen would most likely be associated with depositional areas in the river system). The savings in water column oxygen due to reduced organic loading is expected to be of most benefit in those areas currently at risk for low sediment/water interface dissolved oxygen concentrations.

The projected 44 percent reduction in organic mater is conservative as accounts only for reductions in algal growth within the system. It does not account for any corresponding reduction in attached growth (periphyton, attached macrophytes, etc.) resulting from reductions in nutrient loading. Additionally, it does not account for reduced sediment-oxygen demands from erosion-based sediment reductions occurring with implementation progress.

If substrate dissolved oxygen levels require greater improvements than those identified by nutrient reductions, the TMDL will be re-evaluated. It is recognized that improvement in substrate dissolved oxygen levels will not be instantaneous as there is already a substantial store of organic material available within the SR-HC TMDL system. However, sustained reductions in incoming loads of organic material combined with transport and recycling within the system will, over time, result in decrease in the amount of organic material available within the SR-HC TMDL reach, this will improve substrate dissolved oxygen levels and benefit aquatic life using the sediment/water interface

Modeled Evaluation of Total Phosphorus Target Attainment.

A modeling effort using the USACOE CE-QUAL-W2 model has been undertaken by IPCo for the purposes of improving understanding of the Hells Canyon Complex system as part of the FERC re-licensing effort for the Hells Canyon Complex hydropower facilities (IPCo, 1999d). Because of its potential application to the SR-HC TMDL process, this model was evaluated extensively by the DEQs. The IPCo model has been reviewed and evaluated by modeling experts at IPCo and their contractors, and has been peer reviewed by a panel of modeling experts from several different state and federal agencies that were assembled by IPCo. In addition, the DEQs have evaluated this model and its application to the SR-HC TMDL effort and have conducted a separate peer review through a panel of modeling experts assembled by the DEQs in response to requests voiced by some members of the SR-HC PAT.

Although it was recognized in all peer reviews that no model will ever be a perfect fit for any system, all reviewers from all of the peer review efforts indicated that they felt confident with the manner in which the model had been validated and applied to the Hells Canyon Complex. (For more information on this peer review process please contact the IDEQ Boise Regional Office, 1445 North Orchard, Boise, Idaho 83706.) Because of the outcome of the peer reviews conducted, it is the opinion of the DEQs that the IPCo model represents a valid tool for evaluation of water quality conditions within the SR-HC TMDL reach.

The IPCo model was utilized to simulate the water quality response to the 0.07 mg/L total phosphorus target in the Upstream Snake River segment (RM 409 to 335) and the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Modeling work was accomplished by IPCo and contract personnel. Simulations included a projection of both short-term (benefits that would be realized quickly) and long-term (benefits that would take a more extended period of time to occur) water quality improvements based on the attainment of the 0.07 mg/L total phosphorus target. The following section contains a summary of the information provided by IPCo regarding this modeling effort. The full memorandum is attached as Appendix F.

The changes in water quality in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir were evaluated. The 1995 baseline boundary condition in the Brownlee Reservoir Model is based on the 1995 Southwest Snake River Model (IPCo, 2000a) results calibrated to measured data from Porters Island. The model includes soluble reactive phosphorus and phosphorus tied to organic matter (based on a coefficient for the stoichiometric equivalent between organic matter and phosphorus) (Cole and Wells, 2000; IPCo, 1999d). Thus, organic matter in the boundary condition multiplied by the coefficient represent organic phosphorus in the model.

To evaluate total phosphorus in the model and the reduction to meet the target, total organic matter was calculated as the sum of algae and dissolved and particulate organic matter. Total organic matter was converted to organic phosphorus using a ratio of 100:1 (total organic matter: organic phosphorus) (IPCo, 2000a). Total phosphorus was calculated as the sum of organic phosphorus and soluble reactive phosphorus. The model does not account for inorganic (mineral) phosphorus attached to sediment. The date when total phosphorus exceeded the criteria by the greatest amount was identified in the boundary condition and the difference between the maximum value and the target was calculated. This difference was then used to reduce the algae, organic matter, and soluble reactive phosphorus boundary conditions for the entire year. Model output is displayed in Figure 3.2.14.

As can be seen in Figure 3.2.14, the average modeled chlorophyll *a* concentration in the Upstream Snake River segment (RM 409 to 335) decreases by greater than the calculated 44 percent (estimated ~70%). This is reasonable as the original calculated value focuses on annual average chlorophyll *a* and does not account for other organic matter loads generated instream. Modeled chlorophyll *a* concentrations resulting from the attainment of the 0.07 mg/L total phosphorus target are within the range described in Table 3.2.1 as representing valid maxima for support of aesthetic and recreational designated uses, and match those identified in Table 3.2.6 associated with the 0.07 mg/L total phosphorus target.

To simulate the short term improvements, dissolved phosphorus and organic phosphorus (i.e. organic matter, including algae) were reduced from the 1995 baseline boundary conditions such that inflowing phosphorus levels did not exceed 0.07 mg/L. Long-term phosphorus improvements related to changes in sediment oxygen demand were simulated by replacing baseline sediment oxygen demand values estimated during model optimization with more typical values.

Changes in dissolved oxygen concentrations from each of the simulations were compared to baseline conditions by calculating the percent of volume where dissolved oxygen levels were below dissolved oxygen criteria. Baseline conditions were represented by the peer-reviewed Brownlee Model using 1995 measured boundary conditions, optimized to measured in-reservoir water quality data (IPCo, 1999d).

The simulation results demonstrate improving conditions from short-term conditions without sediment oxygen demand improvements to long-term conditions with sediment oxygen demand improvements. In general, the simulations show an increase in dissolved oxygen in all zones except the riverine zone, where dissolved oxygen is already at super saturated levels as a result

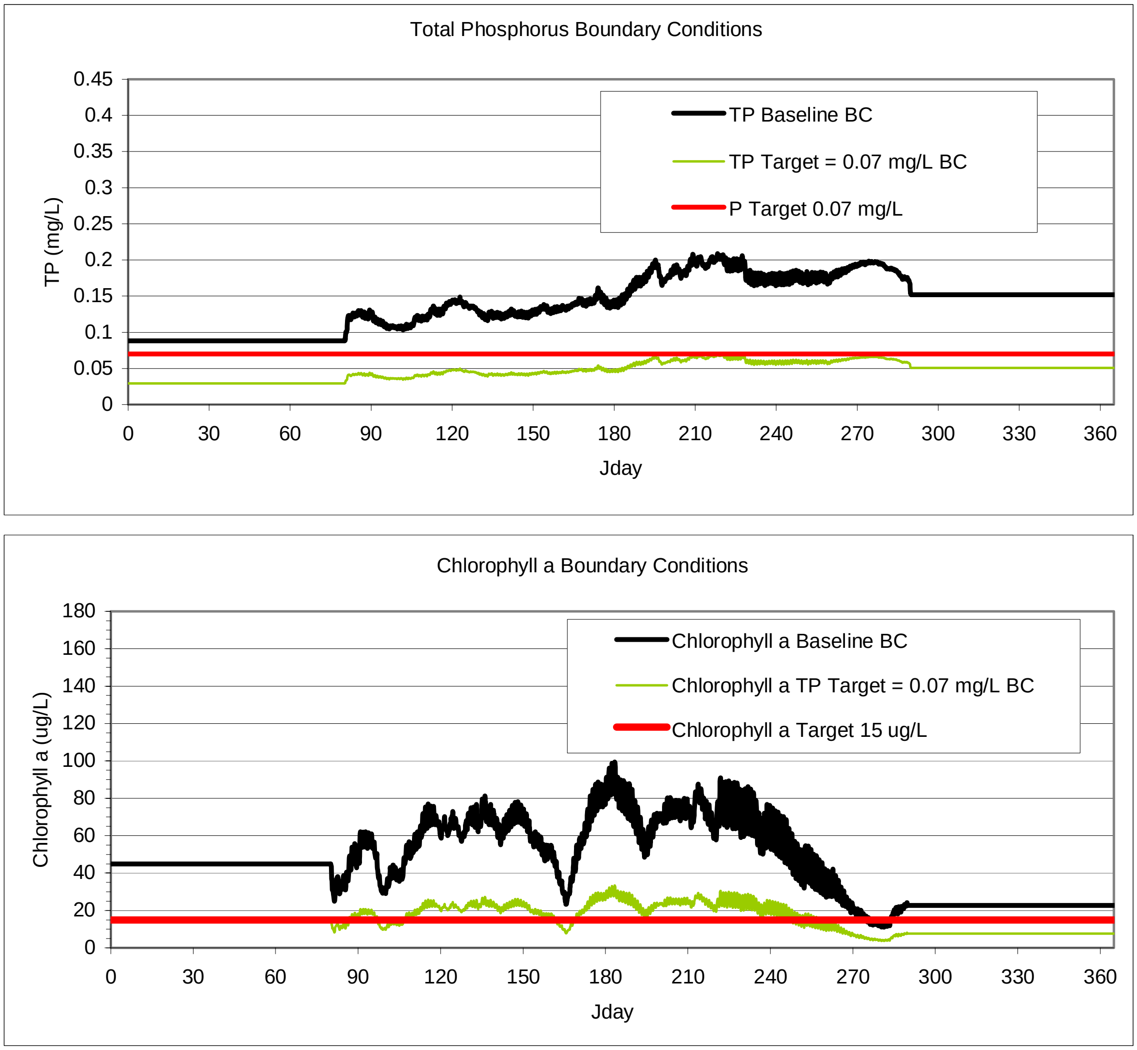


Figure 3.2.14. 1995 Boundary conditions, baseline and modeled total phosphorus target reductions.

of the algal bloom. In general, the dissolved oxygen improvement is greatest in the summer, especially in the metalimnion.

The simulation in Figure 3.2.15 a shows Brownlee Reservoir's initial response to reductions in total phosphorus and organic matter loads based on the total phosphorus target of 0.07 mg/L. When the TMDL is first implemented, sediment oxygen demand will be unchanged from baseline conditions. This limits the initial level of improvement (i.e., increase in dissolved oxygen) in the downstream end of the transition zone and in the lacustrine zone where sediment oxygen demand levels are highest.

The response to these long-term improvements was simulated by reducing sediment oxygen demand to 0.1 gm oxygen m^{-2} day^{-1} throughout the Brownlee Reservoir (Figure 3.2.15 b). This sediment oxygen demand is more typical of naturally occurring sediment oxygen demand levels

(Cole and Wells, 2000). The inflowing boundary conditions are unchanged from the previous simulation.

These simulations show that substantial improvements in water quality in Brownlee Reservoir will occur through implementation of the 0.07 mg/L total phosphorus target proposed for the SR-HC TMDL. While substantial improvements in dissolved oxygen are projected to occur as a result of the attainment of the 0.07 mg/L total phosphorus target, additional improvements are needed to meet dissolved oxygen criteria in Brownlee Reservoir. This is discussed in more detail in Section 3.2.8.7.

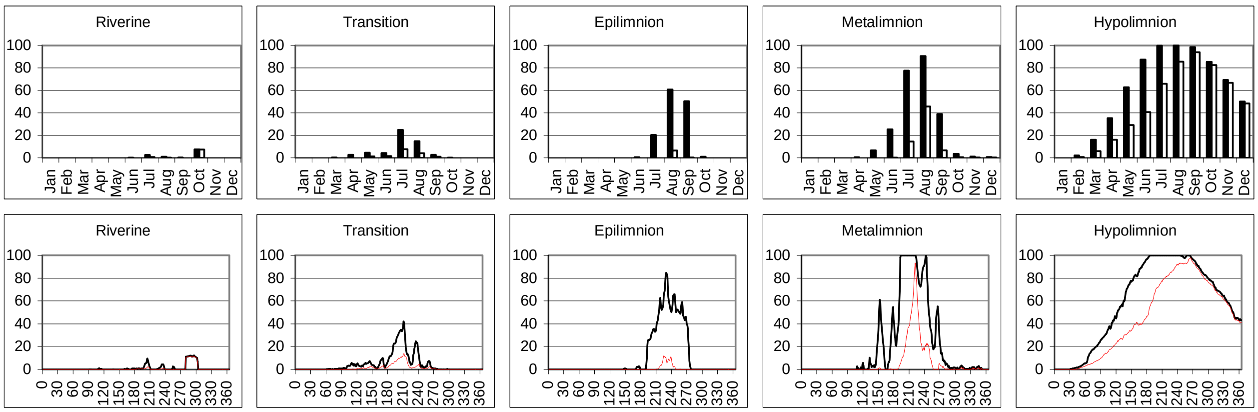


Figure 3.2.15 a. Simulation results showing short-term improvement resulting from implementation of the 0.07 mg/L total phosphorus target. Dark line shows percent dissolved oxygen below criteria (6.5 mg/L) for baseline and light line shows total phosphorus target.

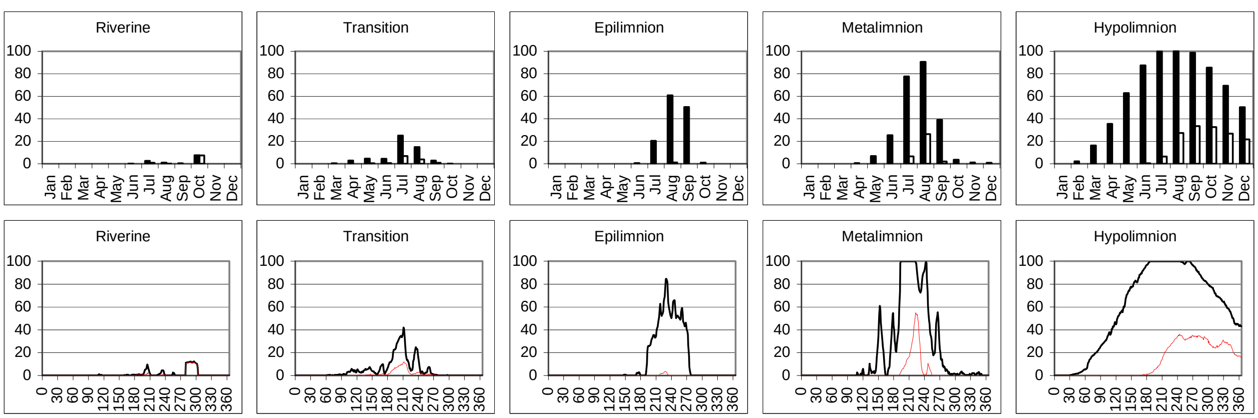


Figure 3.2.15 b. Simulation results showing long-term improvement resulting from implementation of the 0.07 mg/L total phosphorus target and resulting decrease in sediment oxygen demand. Dark line shows percent dissolved oxygen below criteria (6.5 mg/L) for baseline and light line shows total phosphorus target with sediment oxygen demand improvement.

Both calculated and modeled results showed similar increases in water quality through reduced algae (chlorophyll *a*) concentrations and improved dissolved oxygen. Because these evaluations were undertaken using very different methodologies and associated assumptions, the agreement between the two acts to substantiate the predicted outcome.

Other Benefits Projected from Meeting the Total Phosphorus Target.

The reduction in organic matter will also decrease the potential for methylmercury production within the SR-HC TMDL reach. A roughly 44 percent reduction in algae-related organic loading to the SR-HC TMDL reach, and the associated reductions in other aquatic growth through nutrient management will reduce the available organic material and thus reduce the opportunity for of the conversion process. The lack of understanding of the time frame over which it occurs precludes quantification of the actual reduction in methylmercury expected. It is also recognized that this improvement will not be instantaneous as there is already a substantial store of organic material available within the SR-HC TMDL system. However, as incoming loads of organic material decrease over time, and transport and recycling within the system proceeds, the amount of organic material available within the SR-HC TMDL reach will decrease, thus leading to decreased methylmercury concentrations. This in turn will reduce the concerns related to aquatic life and fish consumption by humans and animals.

The reduced growth resulting from a 44 percent reduction in total algal biomass will improve water quality conditions related to domestic water intakes as well, as reduced organic matter will lead to reduced potential for trihalomethane production, fewer filter concerns, and lower corrosive potential as nutrient concentrations decrease.

Finally, the US EPA guidance (US EPA, 2000d) illustrates a water quality continuum where systems exhibiting reference conditions are displayed on the left (lower percentile) of the plotted scale and systems identified as impaired are shifted toward the right (higher percentile) of the plotted scale. Waters in between fall on a continuum that blends gradually from impaired conditions to reference conditions with those on the impaired side of the continuum listed as *at risk*. In attaining this target value, the SR-HC TMDL reach will more closely reflect the most frequently occurring total phosphorus concentrations observed in the Snake River system as a whole, rather than the higher total phosphorus concentrations that currently result in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach being shifted toward the impaired end of the scale.

The target of 0.07 mg/L total phosphorus is slightly higher than that projected statistically for the Snake River upstream of RM 600 (0.065 mg/L total phosphorus), a less impacted system; but represents substantial reductions in total phosphorus loading, nuisance algal growth, and similar reductions in the associated water quality problems identified by this assessment.

As outlined above, the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets are supported by data analysis for the Snake River and the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. They are also supported by the guidance on determining nutrient criteria recommended by US EPA. The data analysis and modeled reductions show that attainment of the target will result in substantial reduction in algal growth (as determined by chlorophyll *a* data) and improved dissolved oxygen concentrations within the Upstream Snake River segment (RM 409 to 335).

Therefore, it is the opinion of IDEQ and ODEQ that attainment of less than or equal to 14 ug/L mean growing season chlorophyll *a* concentration through attainment of the less than or equal to 0.07 mg/L mainstem total phosphorus target will result in reductions in algal growth sufficient to support aquatic life, domestic water supply, recreational and aesthetic uses within the Upstream Snake River segment of the SR-HC TMDL reach and attainment of the water quality standards for both Oregon and Idaho.

3.2.8.7 Identification of Difference in Assimilative Capacity for The Reservoir Segments.

While targets were evaluated separately for the Upstream Snake River segment (RM 409 to 335) and reservoir segments (RM 335 to 247), the Snake River system operates very much as a complete whole. Water quality within the SR-HC TMDL reach moves as a continuous chain, improvements in water quality in one segment will have a positive effect on downstream segments as degraded water quality in upstream segments will result in poor water quality downstream. This is especially true of the relationship between water quality in Brownlee Reservoir and that in Oxbow and Hells Canyon Reservoirs. Improvements in water quality in Brownlee Reservoir will have an immediate and positive effect on water quality in Oxbow and Hells Canyon Reservoirs. For this reason, the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets were evaluated for water quality improvements primarily in Brownlee Reservoir.

As stated previously, the initial strategy for nutrient target identification in the SR-HC TMDL reach was to establish a target appropriate for the Upstream Snake River segment (RM 409 to 335) which represents the dominant inflow to both the Hells Canyon Complex reservoirs and the Downstream Snake River segment (RM 247 to 188). It was theorized that if the Upstream Snake River segment met water quality standards in river, the water quality in Brownlee Reservoir (and the downstream reservoirs) would be improved. The level of improvement realized in the reservoir complex is a function of (1) the dependence of reservoir water quality on inflowing water quality, and (2) the change in assimilative capacity of the system as it moves through the impoundments. Impairment due to the latter is attributable to the reservoir systems; impairment due to the former is attributable to upstream sources.

The 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets described in the preceding sections are based on the needs of the Upstream Snake River segment (RM 409 to 335). These targets were then applied to the reservoir complex (primarily Brownlee Reservoir as it is located the farthest upstream, has the largest volume, and exhibits the greatest occurrence of water quality degradation of the three and therefore is the most sensitive to inflowing water quality).

The loading analysis (Section 3.2.6) clearly demonstrated that the reservoirs act as a sink for pollutants within the SR-HC TMDL system, removing approximately 44 percent of the total phosphorus and 77 percent of the sediment from the water before it reaches the Downstream Snake River segment (RM 247 to 188).

There are no activities associated directly with the reservoirs that act as phosphorus sources such as those identified in the Upstream Snake River segment (RM 409 to 335). However, the reservoirs do change the way the water moves through the system. This in turn can have an influence on how pollutants are processed and transported within the SR-HC TMDL reach.

The influence of the 0.07 mg/L target was investigated by applying the target phosphorus concentration and the reduced algae load to the inflowing waters of Brownlee Reservoir. For the purposes of this analysis it was assumed that all of the inflowing mainstem met the target concentration and showed the same 44 percent reduction in algae mass calculated to occur in the Upstream Snake River segment (RM 409 to 335).

The same assumptions for algae-related organic material, decay of the labile fraction, and organic matter/O_2 demand coefficients were applied in this evaluation as were applied in the evaluation of the Upstream Snake River segment (Section 3.2.8.6). Oxygen savings in the water column (from reduced algae decomposition) were calculated using 1995 flow data as they represented the most complete set and a reasonably average flow year (90% of the 30-year average). Average monthly flows were calculated, as were average monthly dissolved oxygen concentrations for each of the reservoir sections (RM 335 to 285) using information supplied by IPCo on the size and general volume of the reservoir segments (RM 335 to 247). Daily variations in dissolved oxygen were not tracked. Because they process pollutants differently, have somewhat different flow characteristics during stratification, and represent different levels of priority in designated beneficial use support, the sections of Brownlee Reservoir were evaluated separately for dissolved oxygen influences with the identified 0.07 mg/L total phosphorus target.

Brownlee Reservoir was divided into five separate sections (Figure 3.2.16):

- The riverine section (RM 340 to 325)
- The transition zone (RM 325 to 308)
- The lacustrine zone – epiliminion (RM 308 to 285) from surface elevation to 35 m below the surface.
- The lacustrine zone – metalimnion (RM 308 to 285) from 35 m below the surface to 45 m below the surface.
- The lacustrine zone – hypolimnion (RM 308 to 285) from 45 m below the surface to depth.

The volumes of these sections were calculated using information supplied by IPCo (IPCo, 1999d and personal communication, R. Myers and J. Harrison, IPCo, 2001). The values utilized are shown in Table 3.2.7.

Table 3.2.7. Volume information by section for Brownlee Reservoir. (Data provided by Idaho Power Company.)

Reservoir Section	Section Volume (acre-feet)	% of total reservoir
Riverine	179,382	14%
Transition	341,288	27%
Epilimnion	476,410	37%
Metalimnion	153,565	12%
Hypolimnion	122,696	10%
Total	1,273,341	100%

The influence on water quality was evaluated for the summer months when low dissolved oxygen levels most frequently occur. Each reservoir section was evaluated separately to assess the influence of improved dissolved oxygen and reduced phosphorus and algae loading in the inflowing waters. Each section was evaluated as a whole. It was assumed that the dissolved oxygen improvements within each segment were fully mixed, laterally and vertically. The information generated for the existing conditions (pre-target attainment) is shown in Figure 3.2.17.

Calculated dissolved oxygen curves for the transition zone and epilimnion show dissolved oxygen levels dropping below 6.5 mg/L in July, August and September. Minimum concentration values calculated are approximately 5.25 mg/L and 5.5 mg/L respectively. Calculated dissolved oxygen curves for the metalimnion show a more marked and extensive decrease with dissolved oxygen levels dropping below 6.5 mg/L in June, July, August and September. Minimum concentration values calculated are approximately 2.25 mg/L, occurring during the month of August. Calculated dissolved oxygen curves for the hypolimnion show a substantial decrease in dissolved oxygen concentration starting in June and continuing through the fall. Dissolved oxygen levels calculated dropped well below 3.0 mg/L (a situation lethal to most fish) in July and continue to decrease through the fall. Minimum concentration values calculated are approximately 1.25 mg/L, occurring during the month of September.

The curves shown in Figure 3.2.18 are calculated dissolved oxygen concentrations post-target attainment, showing the response of Brownlee Reservoir waters to improved water quality in the inflowing Snake River at RM 335. In all sections of the reservoir, attainment of water quality targets upstream resulted in a dramatic improvement in dissolved oxygen concentrations in the reservoir waters.

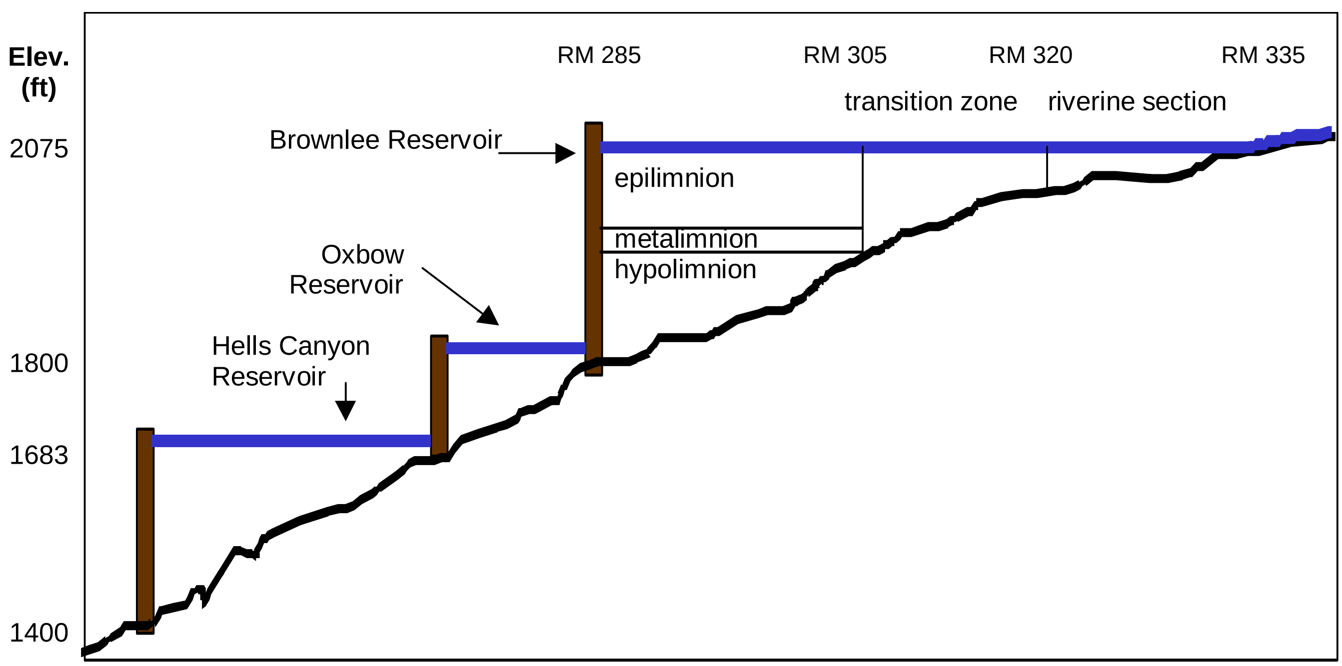


Figure 3.2.16. Diagram of the Hells Canyon Complex showing the dams and the reservoirs and diagramming the separate Brownlee Reservoir sections.

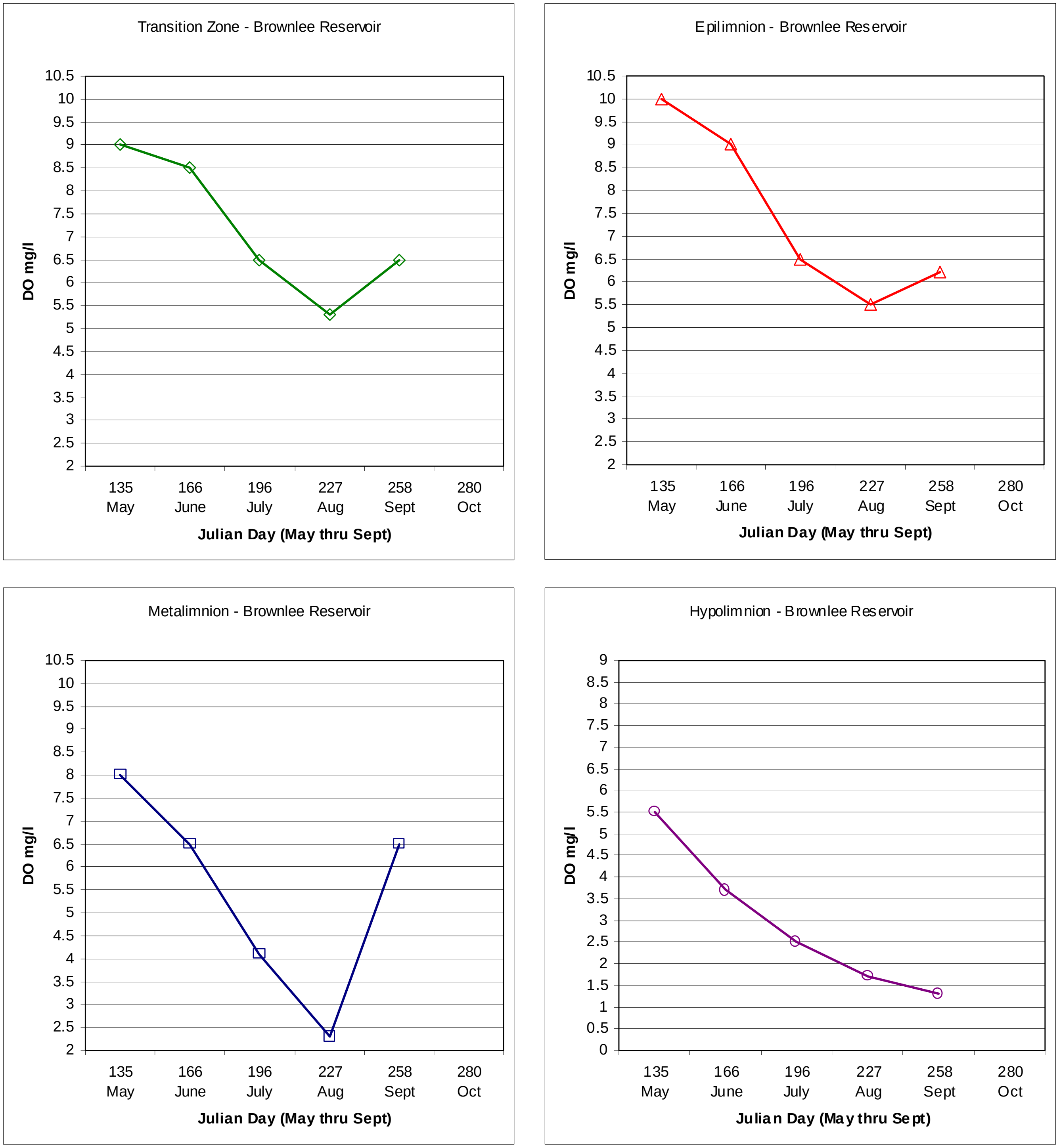


Figure 3.2.17. Calculated dissolved oxygen curves for distinct zones in Brownlee Reservoir (RM 335 to 285) under existing conditions.

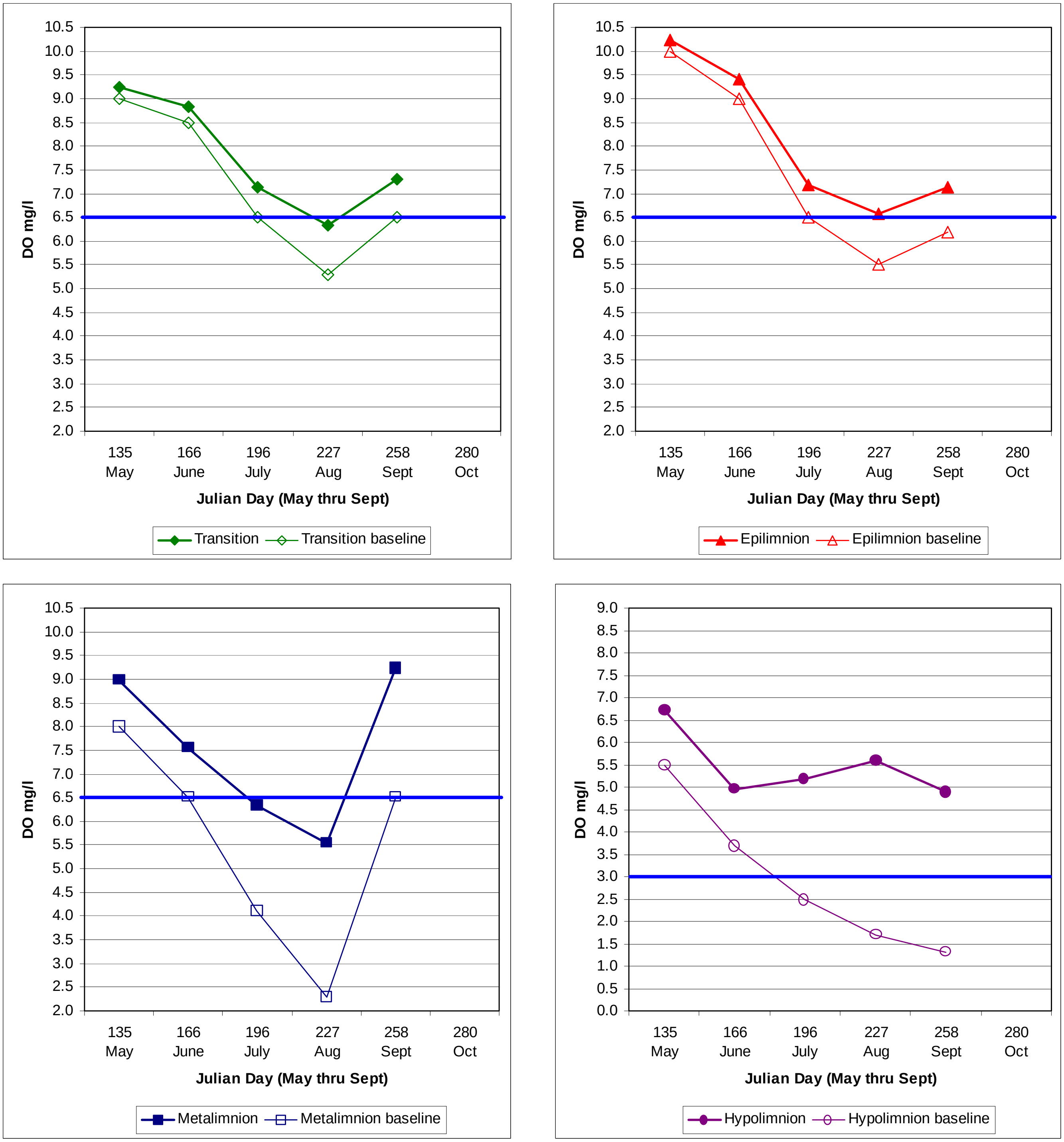


Figure 3.2.18. Calculated effect of improved dissolved oxygen in Brownlee Reservoir (RM 335 to 285) as an effect of attaining the 14 ug/L chlorophyll *a* and 0.07 mg/L total phosphorus concentration targets in the Upstream Snake River segment (RM 409 to 335).

In all cases, low dissolved oxygen conditions were projected to occur to a lesser extent and for a shorter duration under the target conditions than calculated for existing conditions. Dissolved oxygen concentrations were not calculated for the riverine section of Brownlee as the methodology used would result in overestimates due to substantially shorter residence times than those in the transition or lacustrine zones. The curves calculated for existing conditions are also included in the plots for comparison, and are labeled "baseline" conditions for each section.

Calculated post-attainment dissolved oxygen curves for the transition zone show concentrations dropping to or below 6.5 mg/L for approximately 16 days, and *below* 6.5 mg/L for approximately 10 days in early August. Minimum concentration values calculated are approximately 6.3 mg/L. Calculated post-attainment dissolved oxygen curves for the epilimnion show concentrations dropping to but not below 6.5 mg/L for two days in early August. Minimum concentration values calculated are approximately 6.5 mg/L. Calculated dissolved oxygen concentrations for the metalimnion were at or below 6.5 mg/L for approximately 45 days and *below* 6.5 mg/L for approximately 41 days during late July and much of August. Minimum concentration values calculated are approximately 5.5 mg/L, occurring during the month of August.

Calculated dissolved oxygen curves for the hypolimnion show a decrease in dissolved oxygen concentration starting in June and continuing through the fall. Dissolved oxygen levels calculated <u>never</u> dropped below 3.0 mg/L (a situation lethal to most fish). Minimum concentration values calculated are approximately 5.0 mg/L, occurring for approximately two days during the month of June, and approximately 4.9 mg/L, occurring for approximately three days during the month September.

As can be seen from Figure 3.2.18, dissolved oxygen improvements are realized in <u>all</u> sections of the reservoir from application of the 0.07 mg/L total phosphorus target. The improvements calculated for the metalimnion section are the greatest while the increases calculated for the transition zone and epilimnion are the smallest in magnitude. The improvements observed in most cases allow the reservoir sections to meet the water quality target of 6.5 mg/L dissolved oxygen. In those sections and times when dissolved oxygen concentrations are currently very low in Brownlee Reservoir (the metalimnion and hypolimnion in July and August) substantial improvements in dissolved oxygen are realized through the attainment of water quality targets upstream, although the dissolved oxygen target is not attained.

In order to meet water quality targets in Brownlee Reservoir, further implementation of additional mechanisms will have to be employed (in addition to the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets already in place). This difference in assimilative capacity is assumed to be due to the transition from a riverine to a reservoir system. Because this change is anthropogenic in nature, further augmentation of dissolved oxygen in the system will be the responsibility of the impoundments.

Direct calculation of the dissolved oxygen improvements and additional oxygen necessary to meet the water quality target of 6.5 mg/L were completed using the information plotted in Figure 3.2.18 and the reduction in biomass discussed previously. Because of the lack of continuous dissolved oxygen data, linear transitions between dissolved oxygen concentrations were used.

Transitions occurring in the reservoir most certainly do not follow a linear pattern. It is likely that such transitions occurring in the reservoir would describe a more rounded shape with greater temporal variation than described by the calculated curves. The straight-line effects of the calculated dissolved oxygen transitions potentially masks the shoulders of the curves and is a source of error (most probably underestimation) to this analysis. For this reason, an additional margin of safety has been identified.

The identified margin of safety has two purposes in this calculation, to correct for the errors introduced by the linear transitions discussed above, and to be protective over a wide range of water years. Data used in these calculations were from 1995, a relatively average water year (90% of the 30-year average). The identified margin of safety recognizes that dissolved oxygen concentrations in the reservoir will have wider variability than that described by the 1995 data, and seeks to be protective of aquatic life uses.

The calculated time period when post-attainment metalimnetic waters do not meet the 6.5 mg/L target occurs during the months of July and August, a total time period of 45 days where metalimnetic waters are at or below the 6.5 mg/L dissolved oxygen target. Because of the linear transition mechanism used to calculate the change in dissolved oxygen concentration, some exceedences of the target may also occur during the last part of June and the first part of September but are masked by the monthly time step. For this reason, a 65 day period (10 days before and 10 days after the calculated 45 day period of exceedence) was used to calculate the required improvements in dissolved oxygen specific to the metalimnion. This calculation represents a margin of safety of 44 percent. Although it may be an overestimate in some years, this period represents a more protective time frame than the 45 day period calculated directly.

The calculated time period when post-attainment transition zone waters do not meet the 6.5 mg/L target occurs during the months of July and August, a total time period of 16 days where metalimnetic waters are at or below the 6.5 mg/L dissolved oxygen target. Because the same concern regarding the linear transition mechanism used to calculate the change in dissolved oxygen concentration, a 24 day period (4 days before and 4 days after the calculated 16 day period of exceedence) was used to calculate the required improvements in dissolved oxygen specific to the metalimnion. This calculation represents a margin of safety of 50 percent. The time period in which transition zone exceedences occur lies within the exceedence time frame described for the metalimnion. Therefore, while these exceedences will require additional dissolved oxygen be added to the reservoir, they will not necessarily increase the total timeframe over which oxygenation is necessary.

Using the volume of 153,565 acre-feet (Table 3.2.7) and retention times generated for the metalimnion by IPCo, (5 days in July and 8 days in August under full pool (1995) conditions), approximately 1,540 billion liters of water pass through the transition zone and metalimnion during the 65 day period described above.

The total dissolved oxygen mass required to address the loss of assimilative capacity in the metalimnion alone over this time frame is 1,053 tons (957,272 kg). This is equivalent to an even distribution of 16.2 tons/day (14,727 kg/day) over 65 days.

The total dissolved oxygen mass required to address the loss of assimilative capacity in the transition zone alone over this time frame is 72 tons (65,454 kg). This is equivalent to an even distribution of 3.0 tons/day (2,727 kg/day) over 24 days.

Together, these separate loads will require the addition of a calculated 1,125 tons of oxygen (1.02×10^6 kg). When applied in an even distribution, this translates to approximately 17.3 tons/day (15,727 kg/day) for 65 days.

The calculated time period when exceedences occurred in the metalimnion of Brownlee Reservoir is between Julian days 182 and 247 (the first of July through the first week of September) when dissolved oxygen sags are observed to occur to a greater degree than those identified as the result of poor water quality inflowing from the upstream sources. However, this time frame is not a requirement for timing of oxygen addition or other equivalent implementation measures. Timing of oxygen addition or other equivalent implementation measures should be such that it coincides with those real-time periods where dissolved oxygen sags occur and where it will be the most effective in improving aquatic life habitat and support of designated beneficial uses.

To achieve this improvement in dissolved oxygen does not require direct oxygenation of the metalimnetic and transition zone waters. Improvements in dissolved oxygen concentrations can be accomplished through equivalent reductions in total phosphorus or organic matter upstream, or other appropriate mechanism that can be shown to result in the required improvement of dissolved oxygen in the metalimnion and transition zones to the extent required. A reduction of 1.7 million kg total of organic matter/algal biomass would equate to the identified dissolved oxygen mass. This translates to approximately 11,000 kg/day over the critical period (May through September) or 26,000 kg/day over the 65 day period identified in the calculations for reduced assimilative capacity. The total phosphorus load reduction required to achieve this reduction in organic loading is approximately 1,487 kg/day over the critical period (May through September) or 3,500 kg/day over the 65 period identified in the calculations for reduced assimilative capacity. Direct oxygenation is one method by which the additional dissolved oxygen required can be delivered, but it should not be interpreted as the only mechanism available. Cost effectiveness of both reservoir and upstream BMP implementation should be considered in all implementation projects.

Because this requirement for additional dissolved oxygen is specific to Brownlee Reservoir, IPCo (as operator of the Hells Canyon Complex) will be responsible for implementation of these improvements. There are both total phosphorus and dissolved oxygen improvements required within the different segments of the SR-HC TMDL reach. It should be clarified that Upstream Snake River segment (RM 409 to 335) pollutant sources are responsible for those water quality problems occurring in the Upstream Snake River segment (RM 409 to 335). They are not responsible for those water quality problems that are exclusive to the reservoir and that would occur if the waters flowing into Brownlee Reservoir met water quality standards. Similarly, IPCo (as operator of the Hells Canyon Complex) is responsible for those water quality problems related exclusively to impoundment effects that would occur if inflowing water met water quality standards.

Restoring viable concentrations of dissolved oxygen throughout the reservoirs is of highest priority. In the case of the epilimnion and metalimnion, these waters represent primary fish habitat. In the case of the hypolimnion, these waters do not represent the same level of habitat as the metalimnion and epilimnion (IPCo, 2001d). They also represent waters that are more difficult to treat due to low circulation and flushing during stratification. For this reason, the hypolimnetic waters will take longer to meet water quality standards. Sustained reductions over time have been shown to have a positive effect on hypolimnetic waters in other systems and have been projected to occur in Brownlee Reservoir through modeling, but time frames are lengthy, extending many years in some cases (Speece, 1970, 1994, 1996).

In an overall assessment of the immediate benefits, it is obvious that improvements projected to occur in hypolimnetic waters will act to better support designated uses. The dissolved oxygen concentrations, without application of the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets, consistently drop to lethal concentrations, well below 3 mg/L. In all cases with application of the total phosphorus target the dissolved oxygen concentration stayed near or above 3 mg/L. This represents an initial benefit that, combined with the long-term benefits of phosphorus and algae reduction, will result in attainment of non-lethal conditions in the short-term and of water quality standards in the longer-term future.

An additional benefit of the improved dissolved oxygen levels in the transition zone is in the reduced desorption and transformation processes due to the absence of anoxic conditions. The majority of deposition observed in the Hells Canyon Complex occurs in the transition zone of Brownlee Reservoir, which coincides with the area of highest observed sediment-mercury concentrations. By providing sustained dissolved oxygen levels at or above 6.5 mg/L, the pollutant loading associated with this deposition presents a much smaller threat to water quality within the SR-HC TMDL reach and downstream.

Modeled dissolved oxygen improvements provided by IPCo, show a smaller reduction in assimilative capacity than that calculated as discussed above. The total mass of additional dissolved oxygen need projected by the IPCo model was 880 tons total (22 percent difference from the 1,125 tons calculated). The difference may be attributed to the fact that the calculated value (1,125 tons) focuses on annual average chlorophyll *a* and does not account for reductions in other organic matter loads generated instream, or attempt to quantify long-term improvements from reduced loading. The chlorophyll *a* concentrations modeled by IPCo account for reductions in other organic loading to the system and for the reduction in sediment oxygen demand resulting from long-term improvements.

3.2.8.8 Identification of the Critical Period for Target Application.

Because most of the negative effects in the SR-HC TMDL reach associated with elevated nutrient levels stem from excessive algal growth, which is a seasonal occurrence, an evaluation of the critical time period for phosphorus reductions was included as part of the target determination for this TMDL.

Total algal growth and temporal distribution of phosphorus loading was evaluated. Within the mainstem Snake River two general periods of elevated chlorophyll *a* concentration are observed

(Figure 3.2.19). Blooms occur in the mainstem Snake River and in the upstream end of Brownlee Reservoir in the spring (April at RM 385 and May to June at RM 340) and summer (June to July at RM 385 and Aug at RM 340). These periods of growth represent the dominant source of algal biomass to the SR-HC TMDL reach. Other sources of organic material, such as periphyton sloughing, are not well understood. Further investigation of such sources will be carried out as part of the phased implementation process.

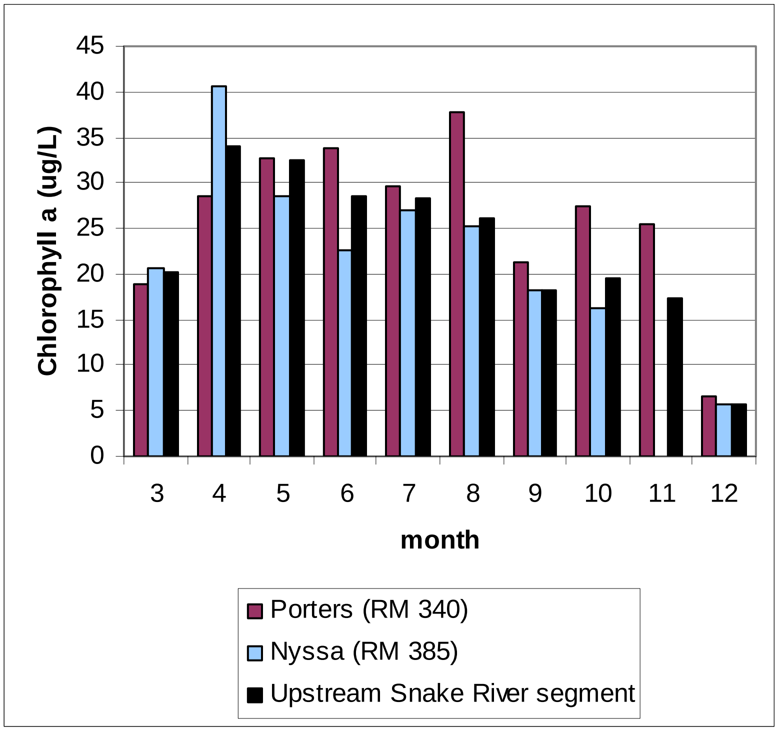


Figure 3.2.19. Temporal distribution of chlorophyll *a* in the Upstream Snake River segment (RM 409 to 335).

Winter conditions do not encourage algal growth as water temperatures are lower and available sunlight is both less intense and of shorter duration. Nuisance level blooms have not been observed to occur during winter months in the SR-HC TMDL reach. Both total phosphorus and chlorophyll *a* concentrations measured in the mainstem Snake River decrease substantially during the late fall and winter months (see Figure 3.2.2 and 3.2.19).

The fact that algae blooms are generally a summer occurrence, and that summer growth appears to be most directly related to the designated use support concerns discussed previously, is an indication that seasonal targets would be appropriate if sufficient reductions could occur during the critical period of algae growth to result in improved water quality and support of designated beneficial uses.

To assess the applicability of a seasonal target, total algal biomass loading was calculated using measured chlorophyll *a* concentrations. The annual distribution of loading was evaluated as shown in Figure 3.2.20.

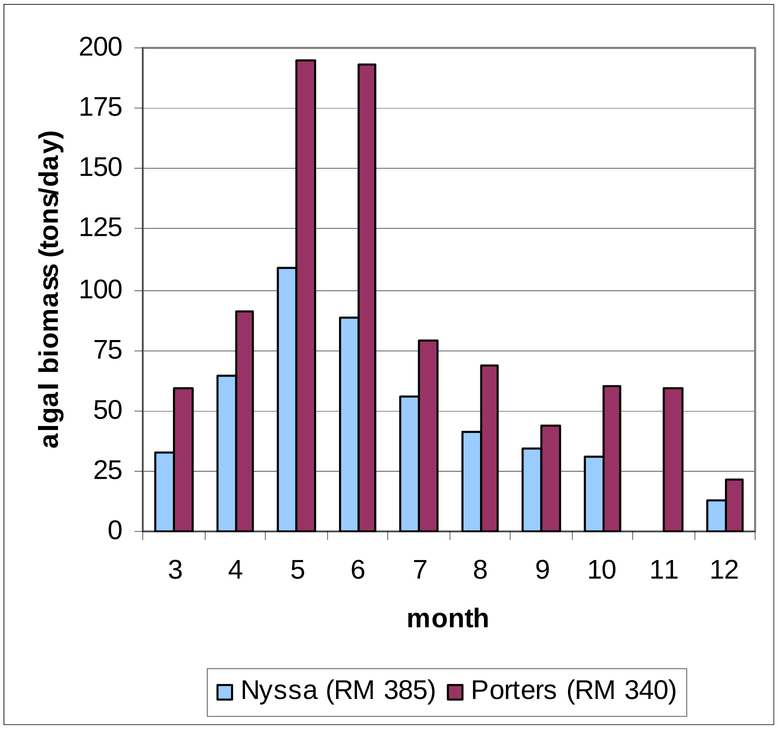


Figure 3.2.20. Temporal distribution of algae biomass loading in the Snake River - Hells Canyon TMDL reach as calculated from measured chlorophyll *a* concentrations.

Several considerations were recognized in the establishment of an appropriate critical period for nutrient reductions.

1. Impairment of the designated recreational and aesthetic use occurred primarily due to algal growth. All complaints received were specific to the summer and early fall months.

2. Concerns related to the potential of non or only partial support of aquatic life uses due to low substrate dissolved oxygen centered primarily on organic matter deposition and decomposition in the river and reservoir headwater areas. This decomposition will occur at a much slower rate in cool water temperatures and is therefore less of a concern in winter and early spring months than in summer and fall months. Nutrient controls will reduce the total amount of algae related growth and deposition overall so that less oxygen depletion occurs as a result of decomposition.

3. Concerns related to increased methylation of mercury due to excessive organic loading are specific to both the organic load and the anoxic conditions documented in Brownlee Reservoir and qualitatively identified in the Upstream Snake River segment (RM 409 to 335). Low dissolved oxygen in these areas is most likely to occur during summer and early fall months. Nutrient controls will reduce the total amount of algae related growth and deposition overall so that less oxygen depletion occurs. Initial calculations show that the areas of greatest

deposition in Brownlee Reservoir and in the Upstream Snake River segment (RM 409 to 335) will benefit from improved dissolved oxygen levels.

4. Domestic water supply concerns regarding trihalomethane production are specific to those time periods when greatest algal biomass is produced (early summer through fall). Filtration concerns are also specific to this time period. Corrosion concerns are specific to time periods with elevated nutrient concentrations. These occur most commonly in the summer and early fall months (Figure 3.2.2).

5. Establishment of critical period should be specific to the needs of the system in supporting designated beneficial uses, but should also recognize naturally occurring exceedences. In the SR-HC TMDL, natural runoff patterns generally occur during the months of March and April. Individual tributary systems may experience earlier or later snowmelt and runoff patterns. BMP-based treatment of snowmelt induced spring flows is not always effective. Both stormwater and agricultural BMPs, if properly installed and operated, will function to reduce this runoff-induced loading, but will function less efficiently in times of substantially increased flow volume, especially if it occurs during a time period when vegetation has not re-established after a winter die-off. Therefore, the highest treatment efficiencies will most likely occur during the summer and fall seasons when vegetation is well established and flows are less than spring runoff volumes.

Given this information, it has been determined that the total phosphorus target identified should be applied in a seasonal fashion that will allow direct management of the water quality concerns associated with nutrient loading. Application of this target over the time frame when conditions favoring algal growth are known to occur (May through September) will result in the reduction of dominant sources of phosphorus in the water shed and system loading in general. With a target application of May through September, it is calculated that approximately 70 percent of the total algal biomass loading can be addressed. The remaining 30 percent of the biomass loading occurs during spring flows, where treatment can occur with stormwater and agricultural BMPs but at reduced efficiency) and during winter months where total loading is minimal and retention within the reservoirs is not slowed by stratification.

This seasonal target will act to reduce both those forms of phosphorus most responsible for algal growth within the system, and algal growth itself. Dissolved phosphorus loading is generally highest during the summer irrigation season in both the mainstem Snake River and the majority of the inflowing tributaries (the Boise River is one exception to this trend as dissolved phosphate concentrations remain relatively steady throughout the year). Thus, application of this target will result in the reduction of the majority of the dissolved phosphate load attributable to anthropogenic sources within the watershed. Dissolved phosphate concentrations throughout the remainder of the year do not pose a substantial concern to water quality as water temperatures are not conducive to excessive growth, and the rapid movement of water through the SR-HC TMDL reach does not result in much retention of this dissolved fraction of the phosphate loading. Additionally, seasonal application of the target will directly address the sediment bound fraction of the total phosphorus loading as it will be in place over the course of the growing and irrigation season.

3.2.9 Reductions Necessary to Meet Nutrient Targets

The specific level of reduction realized by attainment of this target is dependent on the type of water year and the tributary. Setting a concentration-based target means that in high flows, the loading delivered at the target value will be greater than the load delivered at the target value during medium or low flow years. However, the load delivered during high flow years will still be reduced from the load delivered without TMDL-based reductions. Low and average flow years may show a larger relative percentage reduction in nutrient loading by meeting the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets as loading is based on instream flow (load = flow x concentration). High flow years will also see a reduced nutrient load, but the overall relative magnitude of reduction will be smaller due to the higher flows.

Additionally, research performed by both IPCo and Boise City Public Works (Brown and Caldwell) show that some of the most pronounced water quality problems in Brownlee Reservoir have occurred during the longer retention times resulting from low water years. It is theorized that these longer retention times can allow the development of more severe hypoxic and anoxic conditions. Therefore, both flow and retention time, in correlation with pollutant loads and concentrations have the potential to influence water quality in the SR-HC TMDL reach. All of these factors should therefore be considered in the development of the monitoring plans that will be included in the site specific implementation plans prepared following the approval of this TMDL. They will also be considered in the assessment of progress as implementation proceeds.

3.2.10 Load Allocations

Load allocations are discussed in greater detail in Section 4.0. Total phosphorus allocation mechanisms were determined as a result of discussions within the public process and PAT work group products (Appendix I).

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3.3 Pesticide Loading Analysis

3.3.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. Because the SRHC TMDL is a bi-state effort, the most stringent of each state's water quality standards have been identified as the targets for this TMDL. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met.

The Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL reach is listed for pesticides. An evaluation of available data has shown the pesticides of concern specific to the SR-HC TMDL effort to be DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane, CAS #50-29-3), and its metabolites DDD (1,1-dichloro-2,2-bis(p-chlorophenyl) ethane, CAS #72-54-8) and DDE (1,1-dichloro-2,2-bis(chlorophenyl) ethylene, CAS #72-55-9) and dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo,exo-1,4:5,8-dimethanonaphthalene, CAS #60-57-1). The water quality standards and guidance values appropriate to pesticides in the SR-HC TMDL are those that apply to DDT and its metabolites and dieldrin. The water quality targets established for the SR-HC TMDL are based on standards from both Idaho and Oregon. The standards adopted by both states are based on US EPA guidance values (National Toxics Rule and Table 20) (EPA FRL-OW-6186-6a).

DDT: less than 0.024 ng/L water column concentration
DDD: less than 0.83 ng/L water column concentration
DDE: less than 0.59 ng/L water column concentration
Dieldrin: less than 0.07 ng/L water column concentration

These represent the applicable targets for pesticides for the SR-HC TMDL.

3.3.2 Designated Beneficial Use Impairment

There are no data available documenting pesticide concentrations in water, fish tissue or sediment in Oxbow Reservoir. There are no indications of impairment of the designated beneficial uses due to pesticide concentrations in Oxbow Reservoir. No fish consumption advisories for pesticides are currently in place. However, over 95% of the inflow to Oxbow Reservoir is from Brownlee Reservoir, therefore, available data from upstream segments (Upstream Snake River and Brownlee Reservoir) were evaluated. These data show elevated concentrations of fish tissue t-DDT and dieldrin. The US EPA action level for fish tissue DDT was established to address the combination of DDT and its metabolites (known as total or t-DDT). This action level, set at 1.0 mg/kg, was exceeded in 44% of the data. None of the available data showed exceedences of the US EPA action levels for fish tissue concentrations of dieldrin (1.0 mg/kg).

Fish containing high concentrations of pesticides pose a health threat to humans and predatory wildlife that ingest fish tissue. Predatory wildlife most at risk are those predators of older, larger fish such as bald and golden eagles, both of which inhabit areas of the SR-HC TMDL reach.

Water column data from upstream segments is very limited. Only a very small data set was available for water column concentration. All water column samples exceeded the SR-HC TMDL water column targets for DDT and dieldrin. All fish tissue samples exhibited concentrations of DDT and dieldrin above the US EPA screening level. None of the samples exceeded the US FDA action level for DDT and dieldrin in edible fish (Clark and Maret, 1998; Rinella *et al.*, 1994). Only t-DDT (four Snake River sites and five samples in Brownlee Reservoir), and Dieldrin (one sample in Brownlee Reservoir) showed fish tissue concentrations that exceeded the National Academy of Science, National Academy of Engineering (NAS/NAE) criteria. All fish tissue samples collected in this reach were positive for t-DDT. These data do not yield a clear answer on the support status of designated beneficial uses but do indicate that sufficient concern exists to justify the collection of additional water column data in both the Oxbow Reservoir segment (RM 285 to 272.5) and the segments upstream.

3.3.3 Pesticides in Surface Waters

3.3.3.1 DDT.

DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane) is a man-made chemical that was widely used historically to control both insects that could damage agricultural crops and those that carry diseases like malaria and typhus. DDT was discovered in 1873, but was not identified as an insecticide until 1939 when Paul Muller of Geigy Pharmaceutical in Switzerland discovered its effectiveness. He was awarded the Nobel Prize in medicine and physiology in 1948 for this discovery.

The use of DDT increased substantially on a global scale after World War II. It was particularly effective against the mosquito that spreads malaria and lice that carry typhus. The World Health Organization (WHO) estimates that during the period of its use approximately 25 million lives were saved by reducing the spread of these diseases. DDT seemed to be the ideal insecticide as it was cheap and of relatively low toxicity to mammals (oral LD50 is 300 to 500 mg/kg). However, concern over environmental effects began to appear in the late 1940s. Many species of insects were able to develop a resistance to DDT so it was no longer as efficacious a control mechanism. In addition, DDT was also discovered to be highly toxic to fish (ATSDR, 1994b, 2001; Harrison, 2001), and was linked to eggshell thinning in several families of birds (NAS/NAE, 1973; US EPA, 1992c).

Because of the risk it presented to wildlife and the potential human health concerns being raised, the use of DDT was banned (except for public health emergencies), in the United States in 1972 (USFWS, 2002). DDT is however still used in some other countries.

The remarkable chemical stability of DDT and its tendency to bio-concentrate in fatty tissues add to the complexity of the problem of legacy application and current water quality concerns. DDT is not metabolized rapidly; rather, it is stored in fatty tissues within the body. As an average, about eight years are required for an animal to metabolize half of the DDT it assimilates (this eight years is known as the biological half-life). Therefore, if an animal continues to ingest DDT at a steady rate, it will build up over time (Harrison, 2001). The buildup of DDT in natural waters is however, a reversible process. The US EPA reported a 90% reduction of DDT in Lake Michigan fish by 1978 as a result of the ban (Harrison, 2001).

Two similar chemicals (breakdown products of DDT) that are often associated with the presence of DDT in environmental systems are DDE (1,1-dichloro-2,2-bis(chlorophenyl) ethylene) and DDD (1,1-dichloro-2,2-bis(p-chlorophenyl) ethane). While these compounds are breakdown products or metabolites of DDT, DDD was also manufactured to kill pests. Its use has also been banned. DDE has no known commercial use (Harrison, 2001).

3.3.3.2 DIELDRIN.

Dieldrin is also a man-made, chlorinated insecticide; popular for crops like corn and cotton from 1950 to 1970. Dieldrin does not occur naturally in the environment. Because of concerns about damage to the environment and the potential harm to human health, US EPA banned all uses of dieldrin except to control termites in 1974. In 1987, US EPA banned all uses of dieldrin (ATSDR, 2001; NTP, 2001).

In the environment, dieldrin binds tightly to soil. The disappearance of 95% of the original insecticide after application has been shown to require from 5 to 25 years (from references in PMEP, 2001). Volatilization or evaporation to the air is responsible for most of the dieldrin lost from the soil surface. The persistence of dieldrin in the soil is influenced by soil type, where soils with a high organic matter content show higher dieldrin persistence than sandy soils (from references in PMEP, 2001).

Plants take in and store dieldrin from the soil. As with DDT, dieldrin is a very stable chemical and tends to bio-concentrate in fatty tissues. Dieldrin is not metabolized very rapidly and leaves the body very slowly (ATSDR, 2001). Because dieldrin is bioaccumulative, it does not break down easily in the environment and becomes more concentrated as it moves up the food chain to humans and other wildlife (US EPA, 2001f). Dieldrin is a persistent, bioaccumulative, and toxic (PBT) pollutant targeted by US EPA.

As stated above, the Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL reach is listed for pesticides. No data is available to support this listing. However, pesticide data is available for some sites upstream of Oxbow Reservoir, including Brownlee Reservoir, which represents the largest source of inflow to Oxbow Reservoir.

Therefore, existing pesticide data for the SR-HC TMDL reach in total was evaluated. Although several pesticides have been identified in the SR-HC TMDL reach, those pesticides observed to occur at elevated concentrations within this data set were the organochlorine insecticides DDT (and its metabolites), and dieldrin. These compounds were identified as pesticides that should be evaluated within the SR-HC TMDL.

While a state standard-based fish tissue target is not available to this TMDL effort, data collected show these compounds occur in concentrations exceeding the established US EPA screening level for contaminants in edible fish (t-DDT). Concentrations of DDT and dieldrin were also observed to exceed the NAS/NAE criteria to protect fish and wildlife that consume fish within the Upstream Snake River (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. However, none of the data collected show pesticide concentrations in fish tissue that exceed the US FDA action level for contaminants in edible fish.

Neither t-DDT nor dieldrin is highly water-soluble. However, these compounds commonly adsorb onto suspended particles within the water system where they can be deposited on stream, lake and reservoir bottoms and then become re-suspended and transported in a cyclic fashion dependant on flow volume and velocity. Aquatic organisms, especially bottom-feeding species such as suckers, are vulnerable to the bioaccumulation of these compounds.

Both t-DDT and dieldrin are persistent, long lived contaminants. The half-lives (the time it takes for one half of the total mass to degrade) for these compounds have been estimated in the range of hundreds of years. Therefore, even though their use has been discontinued, they are expected to remain in the environment for the foreseeable future (US EPA, 1992a, 1992b and 1992c). This problem is evident throughout the United States. In a national US EPA study (US EPA, 1992a, 1992b and 1992c), over 90 percent of 388 sites sampled nationwide in 1986 and 1989 showed concentrations of DDE (a metabolite of DDT) and PCBs.

3.3.4 Sources

Neither DDT nor dieldrin occur naturally to any appreciable extent in the environment (Harrison, 2001). All sources of these compounds are therefore anthropogenic. Both DDT and dieldrin were used extensively in the United States prior to the 1970’s. Their use was discontinued due to their potential negative effects on humans and wildlife. DDT and dieldrin are considered probable carcinogens in humans (US EPA, 1991a, 1992c, 1994c). The use of DDT in the US has been banned since 1972, and the use of dieldrin was phased out between 1974 and 1987 (US EPA, 1992c).

These compounds entered surface water systems primarily from agricultural nonpoint source runoff and atmospheric deposition. Currently, the primary sources of these compounds in surface waters are legacy deposition and continued agricultural runoff from previously treated areas.

3.3.5 Transport and Delivery

Organochlorine pesticide transport and deposition are, in most cases, directly correlated with the transport and deposition of sediment and organic matter (Clark and Maret, 1998; Maret, 1995a and 1995b; Maret and Ott, 1997; Rinella *et al.*, 1994). As these compounds are no longer in use today, the transport and delivery of pesticides adsorbed to entrained sediment and organic material in the SR-HC drainage is the most likely source of continued loading to the mainstem Snake River within the SR-HC TMDL reach.

3.3.6 Data Available for the Snake River - Hells Canyon TMDL Reach

A pesticide monitoring effort by the USGS from 1992 through 1997 (Clark and Maret, 1998) identified t-DDT and dieldrin concentrations in fish tissues throughout the Snake River and several major tributaries in Idaho. The data showed that concentrations of both t-DDT and organochlorine compounds increased with distance downstream. Reservoir concentrations were somewhat higher overall than tributary concentrations, but the trend was evident in both types of surface waters (Table 3.3.1). Only a very small data set was available for water column concentrations. All eight water column samples, four each for DDT and dieldrin, located in the Upstream Snake River segment (RM 409 to 335) exceeded the SR-HC TMDL water column targets. Over 44% of the fish tissue samples exhibited concentrations of t-DDT above the US EPA screening level. None of the fish tissue samples exhibited concentrations of dieldrin above the US EPA screening level. None of the samples exceeded the US FDA action level for DDT and dieldrin in edible fish (Clark and Maret, 1998; Rinella *et al.*, 1994). Only t-DDT (four Snake River sites and five samples in Brownlee Reservoir), and Dieldrin (one sample in Brownlee Reservoir) showed fish tissue concentrations that exceeded the NAS/NAE criteria. All fish tissue data available in this reach (RM 409 to 285, and 247 to 188) were positive for t-DDT (where t-DDT was calculated as the sum of DDT and all metabolite and degradation compounds if not directly measured.

The available t-DDT data show that total concentrations are highest in fish tissue taken from Brownlee Reservoir, followed by samples taken from the Snake River at Jump Creek (upstream of RM 409). Fish tissue samples taken from the Snake River near the Weiser and Malheur river inflows show concentrations slightly higher than those observed in fish tissue samples taken from the Snake River near the Boise and Owyhee river inflows upstream. A general comparison of the Upstream Snake River segment (RM 409 to 335) data (riverine) to the Brownlee Reservoir segment (RM 308 to 285) (lacustrine) data show an increase in observed t-DDT concentrations in reservoir samples. The mean fish tissue concentration in the Upstream Snake River segment was 990 ug/kg (range = 230 ug/kg to 1,700 ug/kg, median = 964 ug/kg). The mean for the Brownlee Reservoir segment samples was 1,261 ug/kg (range = 96 ug/kg to 3,633 ug/kg, median = 1,099 ug/kg). The Brownlee Reservoir samples showed much greater variation than the Upstream Snake River samples.

Rigorous interpretation of these data for site-specific concentration assessment is not possible, however, as fish tissue data are not necessarily indicative of the conditions of the waters in which they were harvested. Additionally, fish tissue concentrations are dependent on size, age, species, habitat conditions and other factors. Fish often move repeatedly between mainstem and tributary sites. The amount of time spent in any one location, and the life stage and season during which this time was spent, can influence the level of pesticide accumulation dramatically.

Data evaluated show that fish tissue t-DDT concentrations are generally higher in the reservoir system than in the Upstream Snake River segment (RM 409 to 335). These same data show that all of the tributary drainages monitored exhibited some level of fish tissue t-DDT contamination. All sites monitored also showed relatively low concentrations of sediment and water t-DDT concentrations as compared to the observed fish tissue concentrations, indicating the occurrence of bioaccumulation within the aquatic species sampled.

Based on the small data set available, water column t-DDT concentration data exhibit only moderate variation within the Upstream Snake River segment (RM 409 to 335). No water column data are available for the Brownlee Reservoir segment (RM 335 to 285). However, all

Table 3.3.1. Data available showing detectable t-DDT distribution in fish tissue, water and sediment in the Lower Snake River Basin.

Location	Species/ Sample	Pesticide	Conc. (ug/kg)*	Action Level Exceeded?		
				US EPA	SRHC TMDL	US FDA
Snake River at Swan Falls	sucker	t-DDT	230	No	NA	No
Snake River at Jump Creek	catfish	t-DDT	1700	Yes	NA	No
Owyhee River mouth	catfish	t-DDT	1040	Yes	NA	No
Owyhee River mouth	sediment	DDE	10.5	NA	NA	NA
Boise River at Parma	sucker	t-DDT	888	No	NA	No
Boise River at Parma	water	t-DDT	0.003	Yes	Yes	NA
Boise River at Parma	sediment	t-DDT	1.4	NA	NA	NA
Snake River at Nyssa	catfish	t-DDT	776	No	NA	No
Snake River at Nyssa	sucker	t-DDT	593	No	NA	No
Payette River 10 km upstream of mouth	bullhead	t-DDT	120	No	NA	No
Malheur River mouth	catfish	t-DDT	1270	Yes	NA	No
Malheur River mouth	water	t-DDT	0.012	Yes	Yes	NA
Malheur River mouth	sediment	t-DDT	42.3	NA	NA	NA
Malheur River mouth	sediment	DDE	5.8	NA	NA	NA
Payette River mouth	water	t-DDT	0.007	Yes	Yes	NA
Payette River mouth	sediment	t-DDT	23.1	NA	NA	NA
Snake River at Weiser	catfish	t-DDT	1420	Yes	NA	No
Snake River at Weiser	water	t-DDT	0.003	Yes	Yes	NA
Snake River at Weiser	sediment	t-DDT	8.9		NA	NA
Brownlee Reservoir	carp	t-DDT	3633	Yes	NA	No
Brownlee Reservoir	sucker	t-DDT	1505	Yes	NA	No
Brownlee Reservoir	catfish	t-DDT	1099	Yes	NA	No
Brownlee Reservoir	catfish	t-DDT	1080	Yes	NA	No
Brownlee Reservoir	catfish	t-DDT	1300	Yes	NA	No
Brownlee Reservoir	bass	t-DDT	113	No	NA	No
Brownlee Reservoir	crappie	t-DDT	96	No	NA	No
Brownlee at Burnt River	sediment	t-DDT	24	NA	NA	NA
Brownlee at Mountain Man Lodge	sediment	t-DDT	7.5	NA	NA	NA
Downstream Snake River at Pittsburgh Landing	sucker	t-DDT	191.1	No	NA	No
Downstream Snake River at Pittsburgh Landing	sucker	t-DDT	95.2	No	NA	No

* Water samples are whole water reported in ug/L
(Data presented is from Clark and Maret, 1998, Rinella *et al.*, 1994; IPCo, 200d).
US EPA = US Environmental Protection Agency screening level of 10^{-6} for contaminants in edible fish (Nowell and Resek, 1994) for fish tissue samples and 0.001 ug/L DDT water column concentration for chronic exposure (EPA FRL-OW-6186-6a).
SR-HC TMDL = Snake River – Hells Canyon DDT target of 0.000024 ug/L.
US FDA = US Food and Drug Administration action level for contaminants in edible fish (Nowell and Resek, 1994).

water column concentrations measured in the Upstream Snake River segment (n = 4) exceeded the SR-HC TMDL target value for DDT (0.024 ng/L).

Sediment t-DDT data however show greater variation and moderately higher concentrations overall in the Upstream Snake River segment (mean = 19 ug/kg, range = 1.4 ug/kg to 42.3 ug/kg, n = 6) as compared to those observed in the Brownlee Reservoir segment (mean = 16 ug/kg, range = 7.5 ug/kg to 24 ug/kg, n = 2). Bed sediment from Brownlee Reservoir at the Burnt River inflow contained the largest concentrations of organochlorine compounds in the Snake River Basin (Clark and Maret, 1998). The data set for sediment t-DDT concentrations is very small however, and may not be representative of the overall distribution of t-DDT within the SR-HC TMDL reach.

The US Department of the Interior (US DOI) conducted a study in 1990 (Rinella *et al.*, 1994) that included bed sediment data from 14 sites in the Owyhee and Malheur drainages and the Snake River from approximately RM 425 to Brownlee Reservoir. Measurable concentrations of DDE were detected at all 14 sites, and dieldrin was detected at 13 sites. Those sites appropriate to this TMDL effort and the concentrations measured are listed in Table 3.3.1 and Table 3.3.2.

A more recent sediment study (IPCo, 200d) included 42 samples taken from the mainstem Snake River from RM 397 downstream to Brownlee Dam (RM 285). Samples were collected from December 1998 to January 2000. In Brownlee Reservoir, samples were taken approximately every five miles from RM 340 to RM 285. Snake River samples included the mouth of the Owyhee, Boise, Malheur, Payette, Weiser, Burnt and Powder rivers.

This sampling effort detected only one organochlorine compound, DDE. Two Snake River samples, one at the mouth of the Owyhee River and one at the mouth of the Malheur River, exhibited measurable sediment concentrations, 10.5 ug/kg and 5.8 ug/kg DDE respectively. None of the mainstem river samples, in Brownlee Reservoir or the upstream channel, showed detectable concentrations of dieldrin. This study, based on sampling and analytical techniques very similar to those used by Rinella (Rinella *et al.*, 1994), contained a much larger sample set than the 1990 work, but showed dramatically different concentration distributions although detection limits, particle distributions and total organic carbon concentrations were similar in both studies (IPCo, 200d). Additional, long-term data collection is necessary to determine if the lower concentrations observed in the 2000 study are an indication of water quality trends in the SR-HC TMDL reach. If these values were indicative of a trend in water quality, fish tissue concentrations would also be expected to decline over time.

The available dieldrin data from the 1990 study show that fish tissue concentrations were relatively similar throughout the Upstream Snake River segment (RM 409 to 335), increasing slightly within the Brownlee Reservoir samples. A comparison of mean values from the Upstream Snake River segment (riverine) with the Brownlee Reservoir segment (lacustrine) shows only a relatively moderate difference. The mean fish tissue concentration in the Upstream Snake River segment was 32.4 ug/kg (range = 12 ug/kg to 50 ug/kg, median = 30 ug/kg). The mean for the Brownlee Reservoir segment samples was 45 ug/kg (range = 19 ug/kg to 100 ug/kg, median = 37 ug/kg). The Brownlee Reservoir samples showed much greater variation than the

Table 3.3.2. Data available on Dieldrin distribution in fish tissue, water and sediment in the Lower Snake River Basin.

Location	Species/ Sample	Pesticide	Conc. (ug/kg)*	Action Level Exceeded?		
				US EPA	SRHC TMDL	US FDA
Snake River at Jump Creek	catfish	Dieldrin	30	No	NA	No
Owyhee River mouth	catfish	Dieldrin	50	No	NA	No
Boise River at Parma	water	Dieldrin	0.002	No	Yes	NA
Boise River at Parma	sediment	Dieldrin	0.1	NA	NA	NA
Snake River at Nyssa	catfish	Dieldrin	12	No	NA	No
Snake River at Nyssa	sucker	Dieldrin	< 5.0	-	-	-
Malheur River mouth	catfish	Dieldrin	50	No	NA	No
Malheur River mouth	water	Dieldrin	0.007	No	Yes	NA
Malheur River mouth	sediment	Dieldrin	4.1	NA	NA	NA
Payette River mouth	water	Dieldrin	0.001	No	Yes	NA
Payette River mouth	sediment	Dieldrin	0.4	NA	NA	NA
Snake River at Weiser	catfish	Dieldrin	20	No	NA	No
Snake River at Weiser	water	Dieldrin	0.002	No	Yes	NA
Snake River at Weiser	sediment	Dieldrin	0.2	NA	NA	NA
Brownlee Reservoir	sucker	Dieldrin	19	No	NA	No
Brownlee Reservoir	carp	Dieldrin	37	No	NA	No
Brownlee Reservoir	catfish	Dieldrin	20	No	NA	No
Brownlee Reservoir	catfish	Dieldrin	100	No	NA	No
Brownlee Reservoir	catfish	Dieldrin	50	No	NA	No
Brownlee Reservoir	sm bass	Dieldrin	< 5.0	-	-	-
Brownlee Reservoir	white crappie	Dieldrin	< 5.0	-	-	-
Brownlee at Burnt River	sediment	Dieldrin	7	NA	NA	NA
Downstream Snake River at Pittsburgh Landing	sucker	Dieldrin	< 5.0	-	-	-
Downstream Snake River at Pittsburgh Landing	sucker	Dieldrin	3.8	No	NA	No

* Water samples are whole water reported in ug/L
(Data presented is from Clark and Maret, 1998, Rinella *et al.*, 1994; IPCo, 200d).
US EPA = US Environmental Protection Agency screening level of 10^{-6} for contaminants in edible fish (Nowell and Resek, 1994) for fish tissue data and 0.056 ug/L water column concentration for chronic exposure (EPA FRL-OW-6186-6a).
SR-HC TMDL = Snake River – Hells Canyon dieldrin target of 0.00007 ug/L.
US FDA = US Food and Drug Administration action level for contaminants in edible fish (Nowell and Resek, 1994).

Upstream Snake River samples. In the small data set available for dieldrin, over 73% of the fish tissue data points (n = 16) showed concentrations of dieldrin that were above the detection limits.

As with t-DDT data discussed above, it should be kept in mind that fish tissue data are not necessarily indicative of the conditions of the waters in which they were harvested as move back and forth between mainstem and tributary sites. The size, type and age of the fish, environmental conditions, the amount of time spent in any one location, and the life stage and season during which this time was spent, can influence the level of pesticide accumulation dramatically.

Data available show that fish tissue dieldrin concentrations in the 1990 study were generally higher in the reservoir system than in the Upstream Snake River segment (RM 409 to 335). These same data show that all of the tributary drainages monitored exhibited some level of fish tissue dieldrin contamination. All also showed relatively low concentrations of sediment and water column dieldrin concentrations as compared to the observed fish tissue concentrations, indicating substantial bioaccumulation within the aquatic species sampled.

No water column dieldrin data is available for the Brownlee Reservoir segment (RM 335 to 285), and only a single sediment dieldrin data point is available for Brownlee Reservoir. Therefore, a comparison of upstream to reservoir segments is not possible. However, all water column concentrations measured in the Upstream Snake River segment (n = 4) exceeded the SR-HC TMDL target value for dieldrin (0.07 ng/L).

The relative amount of t-DDT in fish tissue within the SR-HC TMDL reach is over 30 times that of dieldrin in the Upstream Snake River segment (RM 409 to 335) and over 28 times that of dieldrin in the Brownlee Reservoir segment (RM 335 to 285) for the 1990 study data. This is influenced by the difference in water column and lipid solubility of these compounds and the relative efficiency of uptake and excretion processes within aquatic species. It may also be influenced to a small extent by the relative differences in sediment concentration observed. (The mean t-DDT concentration in sediments is nearly 8 times that of dieldrin.)

From the data in the tables and studies discussed above it is evident that t-DDT and dieldrin are present in the Upstream Snake River and Brownlee Reservoir segments of the SR-HC TMDL, although it is not clear to what extent they still occur, as detectable sediment concentrations were generally observed only in the 1990 study, not the more extensive 2000 study.

It was also observed that tributary drainages to the SR-HC system exhibit similar pesticide pollutant loading concerns. Given the fact that the vast majority of water entering Oxbow Reservoir (greater than 99%) comes directly from Brownlee Reservoir, it is assumed that a portion of the organochlorine insecticide load in Brownlee Reservoir is transferred to Oxbow Reservoir. The relative proportion of this loading however, is unknown. It is assumed that the sediment trapping characteristics of Brownlee Reservoir act to inhibit the direct transport of sediment bound organochlorine insecticides between the two reservoirs. The validity of the pesticide listing in Oxbow cannot be directly assessed without further data collection. The presence of a general concern associated with t-DDT and dieldrin in the Upstream Snake River and Brownlee Reservoir segments however, is clearly demonstrated by the available data.

3.3.7 Determination of Pesticide Loading

Given the available data set, a rough approximation of pesticide loading to the SR-HC TMDL reach has been calculated. Since data are available for the Upstream Snake River segment (RM 409 to 335) only, loading at the USGS gage at Weiser (mainstem Snake River) is calculated to be approximately 42 kg/year (mean) for t-DDT and approximately 28 kg/year for dieldrin for an average water year. The calculated load capacity of the SR-HC TMDL reach at RM 351 (Weiser, Idaho) is approximately 0.34 kg/year t-DDT and 0.98 kg/year for dieldrin. Assuming that the data collected were representative of the average annual concentrations in the water column, this shows that the current pesticide loading is between 30 and 100 times greater in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach than the targets would allow.

All of this loading is the result of legacy application and transport. None of the load is from natural sources. None of the load is assumed to be from current application as both of these compounds are no longer in use.

While this serves to determine a relative loading value, these calculations are very approximate due to the small data set, and cannot be used to specify localized loading to an appropriate level of accuracy. Concentrations were measured only one time, and do not cover the variability of flow or transport conditions that occur over the course of the year. Additionally, load allocations for t-DDT and dieldrin are already established at zero levels within the basin by previous bans on usage (US EPA, 1992c). Therefore, even if sufficient data were available to calculate loading, no allocation mechanism exists to more stringently address the reduction of t-DDT and dieldrin.

The majority of the pesticide load associated with these compounds is accepted to be associated with sediment transport from areas of legacy application. While some legacy application undoubtedly occurred within the direct drainage of the SR-HC TMDL reach, it is most probable that the majority of the application occurred in the tributary and upstream drainages as they represent a larger proportion of the overall agricultural land surface than the direct drainage. Indirect mechanisms will therefore be the primary means for reducing the loading of these pollutants within the SR-HC TMDL reach.

Determination of pollutant loading to a surface water system is generally accomplished through an association of concentration and flow values. Without sufficient water column concentration data for the SR-HC system, calculated loading can only be used as a general indicator of level of concern. Therefore, alternative methods of assessing pesticide loading have been investigated.

3.3.8 Load Allocations and Other Appropriate Actions

Load allocations for t-DDT and dieldrin are discussed in Section 4.0 of this document. All current loading of these pesticides is considered background from legacy sources.

3.3.8.1 Data Collection

Additional data will be collected as part of the phased implementation process to assess the extent of pesticide pollutant loading to Oxbow Reservoir. The data collected during the first phases of the Implementation Plan will be assessed using the current water quality parameters, and the approach and implementation measures outlined here (and in greater detail in the source specific implementation plans) and will be assessed for appropriateness and applicability. In correlation with this effort, reasonable and prudent measures will be identified and implemented to reduce the loading to the Upstream Snake River and Brownlee Reservoir segments, therefore reducing the loading to Oxbow Reservoir. If measures identified herein are determined to be adequate to meet the target criteria, implementation efforts will continue as outlined. If new information identifies additional measures that need to be taken, these will be incorporated into the TMDL and Implementation Plan outline.

3.3.8.2 Pesticide Reduction through Direct Sediment Removal.

Direct removal of pesticides deposited in sediments is not feasible in most areas of the SR-HC TMDL reach. Most sources of legacy pesticides in the area are diffuse in nature and do not stem from a discreet source, but rather from historical application on agricultural lands or deposition from surface water transport. Removal of the sediments and organic material associated with these compounds would potentially result in degradation of other habitat parameters.

3.3.8.3 Pesticide Reduction through Sediment Control/Reduction.

While direct removal of pesticide pollutants is not feasible in the SR-HC TMDL reach, management practices can be targeted to reduce further transport to surface water systems. As identified previously, pesticide transport and deposition are, in most cases, directly correlated with the transport and deposition of sediment and organic matter (Clark and Maret, 1998; Maret, 1995a and 1995b; Maret and Ott, 1997; Rinella *et al.*, 1994). Reductions in the amount of these materials entering the SR-HC system will therefore result in reduction of pesticide pollutant transport and loading to the system. Reduction of such transport will be directly linked to the sediment reduction measures identified within this and other, related TMDLs in the Snake River Basin.

It should be clearly stated that this strategy of legacy pesticide management in no way is intended to require direct monitoring of loading or load reductions. Such monitoring for nonpoint source loading is not feasible and will therefore not be required as part of this TMDL process. Rather, appropriate management techniques specific to proper stewardship will be employed as part of the overall TMDL implementation process. These management techniques are projected to result in reduction of overall DDT and dieldrin loading related to nonpoint source discharge to the mainstem Snake River.

3.3.8.4 Pesticide and Sediment TMDLs in Tributary Systems.

TMDLs directly addressing pesticides will be written for the Owyhee and Malheur rivers by the State of Oregon in 2006 and 2003 respectively. The efforts associated with implementation of these TMDLs will also help to reduce the amount of t-DDT and dieldrin loading to the system by addressing erosive processes.

Indirect reductions in pesticide loading to the SR-HC TMDL reach will also be realized from sediment control measures on inflowing drainages as much of the pesticide loading to the system is thought to occur from pesticides bound to sediment and organic material (Maret, 1995a and 1995b; Maret and Ott, 1997; Clark and Maret, 1998; Rinella *et al.*, 1994). Sediment TMDLs will be written for tributaries to the Owyhee River, Burnt River and tributaries and Powder River and tributaries in 2005 and 2006 by the State of Oregon. Sediment TMDLs have been written for the Mid-Snake and Lower Boise rivers and will be written for the Weiser River and the tributaries to the Weiser and Payette Rivers in 2003 and 2006 by the State of Idaho. The efforts associated with implementation of these TMDLs will also help to reduce the amount of t-DDT and dieldrin loading the system by addressing erosive processes.

3.3.8.5 Reductions Due to Discontinued Use.

Maret (1995a and 1995b), in an intensive study of available data on pesticides in fish tissues observed DDT and its metabolites and PCBs in most of the fish tissue sampled from the Upper

Snake River Basin between 1970 and 1990. His analysis identified a general trend of decreasing concentrations for DDT, its metabolites and dieldrin in the Upper Snake River Basin over time during this period. This decline is assumed to be the result of a combination of discontinued use, improved land management practices, and, to a smaller extent, degradation of existing loads. A similar decline is expected to be occurring in the Lower Snake River Basin. This decline will be enhanced by the implementation of appropriate sediment control measures within this and other TMDLs in the Lower Snake River Basin.

3.3.8.6 Other Protective Measures.

In addition to the sediment control measures implemented through the TMDL processes in the Snake River Basin, existing fish consumption advisories for mercury in the SR-HC TMDL reach target the same populations that would be at risk from bioaccumulation of pesticides in fish tissue. These advisories will act, in an indirect fashion, to protect the designated beneficial use of fishing.

3.4 Bacteria and pH Loading Analyses

3.4.1 Bacteria Loading Analysis

The Upstream Snake River segment (RM 409 to RM 335) is listed for bacteria. Previously, both Oregon and Idaho bacteria criteria were based on fecal coliform bacteria levels. Currently, criteria of both Oregon and Idaho require waterbodies where primary contact recreation occurs to contain less than 126 *E. coli* organisms/100 mL water, and less than 406 *E. coli* organisms/100 mL of water in areas where secondary contact recreation occurs (Table 2.2.1 and Table 2.2.2).

Elevated concentrations of bacteria in surface waters can result in health risks to individuals who are swimming, water skiing or skin diving (primary contact recreation) or other activities that carry the risk of ingestion of small quantities of water. This is of particular concern to the SR-HC TMDL reach as recreation is a significant use of the waterbody.

Common sources of bacteria in surface water include improperly treated sewage and septic systems as well as wastes from warm-blooded animals.

A more detailed discussion of concerns and sources of bacterial loading is available in Section 2.3.1.2.

3.4.1.1 Data Analysis.

Both *E. coli* and fecal coliform data have been used in the assessment of current and historical bacteria violations in the SR-HC TMDL reach. Current data collection allowed *E. coli* levels to be evaluated in the Upstream Snake River segment (RM 409 to 285) of the SR-HC TMDL reach. More detailed information including monitoring dates and sources is available in Section 2.3.1.2.

This listing has been evaluated using available data collected from within this segment from 1978 until present, particularly with available recent data correlated with areas and periods of recreation use. The data show that bacteria counts (*E. coli* and fecal coliform) have not exceeded water quality criteria for primary or secondary contact recreation within the Upstream Snake River segment (RM 409 to 285) of the SR-HC TMDL reach over this time period.

Table 3.4.1 shows summary bacteria data for the 1999 season. These data were collected in an appropriate fashion for evaluation of the 30-day log mean, with a minimum of 5 samples over an appropriate time period collected at most sampling locations. This monitoring was undertaken during the summer season and correlates well not only with the period of time that conditions in the river would be conducive to bacterial growth, but also to the season of greatest primary contact recreation use. Thus, they represent the critical time period for violations within the segment.

3.4.1.2 Appropriate Actions.

Based on these data, the SR-HC TMDL process recommends that the mainstem Snake River (RM 409 to RM 347, OR/ID border to Scott Creek inflow) be delisted for bacteria by the State of Idaho as part of the first 303(d) list submitted by the State of Idaho subsequent to the approval of the SR-HC TMDL (Table 3.4.2). The SR-HC TMDL process further recommends that

Table 3.4.1. Summary bacteria data for the 1999 season in the Upstream Snake River segment (RM 409 to 285) of the Snake River - Hells Canyon TMDL reach.

RM	Number of Samples	E. coli (#/100 mL)	
		Mean	Maximum
335	3	13	22
340	15	11	53
385	7	18	37
403	8	19	91

Table 3.4.2. Appropriate actions for bacteria in the Snake River - Hells Canyon TMDL reach.

Segment	Point Source Allocations/Appropriate Actions	Nonpoint Source Allocations/Appropriate Actions
Upstream Snake River (RM 409 to 335)	data support delisting recommend delisting	data support delisting recommend delisting
Brownlee Reservoir (RM 335 to 285)	not listed	not listed
Oxbow Reservoir (RM 285 to 272.5)	not listed	not listed
Hells Canyon Reservoir (RM 272.5 to 247)	not listed	not listed
Downstream Snake River (RM 247 to 188)	not listed	not listed

monitoring of bacteria levels (*E. coli*), especially in those areas of the SR-HC TMDL reach where recreational use consistently occurs, continue to be an integral part of the water quality monitoring of the Upstream Snake River segment (RM 409 to 285).

It should be noted that this recommended delisting is based only upon the assessment of what is required to attain water quality standards in the mainstem Snake River. No assessment of tributary water quality has been attempted in this TMDL, and conditions specific to bacteria occurring in the mainstem may not reflect conditions occurring in the tributaries. Thus, it is possible that bacteria concentrations in the tributaries to the mainstem Snake River exceed state water quality criteria. Tributary TMDLs could require reductions and could find conditions different from those assumed herein.

In addition, this TMDL does not address bacterial reductions currently required in the Lower Payette River TMDL (IDEQ, 1999b) to meet water quality standards in that tributary.

3.4.2 pH Exceedence Analysis

pH is an indicator of the acidity or alkalinity of a system. Extreme levels of pH can be directly toxic to aquatic life. Even at less extreme levels either acid or alkaline conditions can cause chemical shifts in a system that can result in the release of metallic compounds from sediments in acid conditions or increased ammonia toxicity and release of sorbed phosphorus at high pH levels.

In order to meet the water quality criteria of both states, a pH range of 7 to 9 units has been established as a target for the SR-HC TMDL process to support designated aquatic life beneficial uses within the SR-HC reach. This target has been identified to provide appropriate habitat for fish (including salmonids) and other aquatic life.

Sources of possible pH modification include discharge of acidic or alkaline industrial or municipal wastes, ammonia production during organic matter decomposition, agricultural runoff, and excessive algal growth. However, in this reach, pH is buffered by naturally occurring mineral salts so changes, when they occur, are usually small.

A more detailed discussion of concerns related to and sources of pH modifications is available in Section 2.3.1.2.

3.4.2.1 DATA ANALYSIS.

Upstream Snake River Segment (RM 409 to 285). Data collected from 1968 to 1974 in the Upstream Snake River segment show pH values ranging from 7.5 to 9.0 at RM 361 (near Weiser, Idaho) and between 7.7 and 8.5 slightly upstream from RM 409 (near Marsing, Idaho). These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974 and 1975). Data collected from 1975 to 1991 show pH values ranging from 7.5 to 9.1 at RM 361 (near Weiser, Idaho). Exceedences of the pH target for the SR-HC TMDL occurred less than 1% of the time. A study over a similar time period but with less frequent sampling slightly upstream from RM 409 (near Marsing, Idaho) showed a range of pH values from 7.5 to 8.9. These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974 and 1975). Data collected by IPCo during 1995 at three locations in the Upstream Snake River segment of the SR-HC TMDL reach show pH levels that range from 8.2 to 8.9 near RM 409, Adrian, Oregon; from 7.1 to 8.9 near RM 385, Nyssa, Oregon; and from 8.3 to 9.0 at RM 340, near Weiser, Idaho. An evaluation of all available pH data for the Upstream Snake River segment of the SR-HC TMDL reach shows less than 1% exceedence of the 7.0 to 9.0 pH target (greater than 300 data points). Data ranges for the Upstream Snake River segment are shown in Figure 2.3.9.

Brownlee Reservoir. Data collected from 1968 to 1974 near Brownlee Dam show pH values that average 8.0. No depth information is available with these data so location and water column variations are not known. These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974 and 1975). An evaluation of all recent (1992, 1995, 1997) inflowing and mainstem pH data showed the lowest pH observed in the Brownlee Reservoir to be 7.4. The highest pH observed was 9.6 (IPCo, 1999d, 2000a, 2000c). Less than 5 % of the data were outside of the pH target established for this TMDL process (out of 529 data points, 25 data points showed exceedences, 4.7%). Figure 2.3.17 shows a summary of pH data for 1992, 1995, and 1997.

A more detailed discussion of data available is included in Section 2.3.1.2 and Section 2.3.2.2.

3.4.2.2 Appropriate Actions.

Based on these data, the SR-HC TMDL process recommends that the mainstem Snake River from RM 409 to RM 347 (OR/ID border to Scott Creek inflow) and from RM 335 to RM 285 (Brownlee Reservoir) be delisted for pH by the State of Idaho as part of the first 303(d) list submitted by the State of Idaho subsequent to the approval of the SR-HC TMDL (Table 3.4.3). The SR-HC TMDL process further recommends that monitoring of pH continue to be an integral part of the water quality monitoring of the Upstream Snake River segment (RM 409 to 285).

Table 3.4.3. Appropriate actions for pH in the Snake River - Hells Canyon TMDL reach.

Segment	Point Source Allocations/Appropriate Actions	Nonpoint Source Allocations/Appropriate Actions
Upstream Snake River (RM 409 to 335)	data support delisting recommend delisting	data support delisting recommend delisting
Brownlee Reservoir (RM 335 to 285)	data support delisting recommend delisting	data support delisting recommend delisting
Oxbow Reservoir (RM 285 to 272.5)	not listed	not listed
Hells Canyon Reservoir (RM 272.5 to 247)	not listed	not listed
Downstream Snake River (RM 247 to 188)	not listed	not listed

It should be noted that this recommended delisting is based only upon an assessment of what is required to attain water quality standards in the mainstem Snake River. No assessment of tributary water quality has been attempted in this TMDL, and conditions specific to pH occurring in the mainstem may not reflect conditions occurring in the tributaries. Thus, it is possible that pH levels in the tributaries to the mainstem Snake River exceed state water quality criteria. Tributary TMDLs could require implementation and could find conditions different from those assumed herein.

3.5 Sediment Loading Analysis

3.5.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. Because the SR-HC TMDL is a bi-state effort, the most stringent of each state's water quality standards have been identified as the targets for this TMDL. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met.

The Upstream Snake River segment (RM 409 to 335), the Brownlee Reservoir segment (RM 335 to 285) and the Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL reach are listed for sediment on the state 303(d) lists for this TMDL. The water quality standards and guidance values identified for sediment by the states are narrative criteria that require that sediment shall not exceed quantities that impair designated beneficial uses. These criteria are linked to turbidity and state that turbidity should be less than 50 nephelometric turbidity units (NTU) above background for any given sample and less than 25 NTU for any ten consecutive days. This latter discussion was originally developed to address point sources and incorporates mixing zones in the evaluation of violations.

A narrative standard for sediment is appropriate given that wide ranges of sediment concentration and duration occur in surface waters. Interpretation of the narrative standard on a site-specific basis is necessary to identify targets that will protect designated beneficial uses within the listed segment. The designated beneficial uses within the SR-HC TMDL reach determined to be most at risk from excess sediment were those associated with aquatic life. Because sediment includes both organic and inorganic materials, direct and indirect impacts to aquatic life are possible.

Direct effects such as scale erosion, sight impairment and gill clogging are commonly associated with the duration of occurrence of a specified sediment concentration. Newcombe and Jensen (1996), in a review of 80 published reports on suspended sediment in streams and estuaries reported that lethal effects in rainbow trout begin to be observed at concentrations of 50 mg/L to 100 mg/L when those concentrations are maintained for 14 to 60 days. Similar effects are observed for other species (CH2MHill, 1998).

Indirect impacts associated with sediment in the SR-HC TMDL reach include low dissolved oxygen concentrations due to the decomposition of organic sediment materials, and water column enrichment by adsorbed pollutants. A more detailed discussion of these concerns is included in the Subbasin Assessment for the SR-HC TMDL.

Therefore, sediment loading within the SR-HC TMDL reach is of concern for aquatic life designated beneficial use support, and also because of the attached pollutant loads (nutrients, pesticides and mercury) that the sediment carries. In the SR-HC TMDL, sediment targets and monitored trends will function as an indicator of changes in transport and delivery for these attached pollutants.

3.5.1.1 SNAKE RIVER - HELLS CANYON TMDL WATER QUALITY SEDIMENT TARGETS.

Specific to direct negative effects on aquatic life, and indirect negative effects to the system linked to the transport of adsorbed pollutants, the sediment target for the SR-HC TMDL has been set at less than or equal to 80 mg total suspended solids/L for acute events lasting no more than 14 days, and less than or equal to 50 mg total suspended solids/L as a monthly average. Available information utilized in the determination of this target included both site-specific data and literature values. A more detailed discussion of the reasoning behind this target is outlined in the following sections of this document.

It is the professional opinion of IDEQ and ODEQ that these targets will be protective of both aquatic life (EIFAC, 1964; NAS/NAE, 1973; IDEQ, 1991; CH2MHill, 1998; Newcombe and Jensen, 1996) and water quality, and will meet the requirements of the CWA. The identification of the short term 80 mg/L target will allow natural runoff and storm events (for which aquatic life in the SR-HC TMDL reach are adapted) to be accommodated for by the TMDL. It is the professional opinion of IDEQ and ODEQ that attainment of these targets represent a valid interpretation of narrative standards and will result in support of the designated beneficial uses within the system.

3.5.2 Designated Beneficial Use Impairment

Duration data is critical in determining direct effects to aquatic life within the SR-HC TMDL reach. No such duration data is available to this TMDL effort. It will be collected as appropriate as part of the monitoring undertaken in the first phase of implementation following approval of this TMDL. The data collected will be assessed to determine effects on aquatic life within the SR-HC. This information will be incorporated into the TMDL as part of the iterative process.

Data is available that show indirect negative effects on aquatic life in the form of low dissolved oxygen (in the reservoir complex) and high productivity levels (in both the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir). (This data is discussed in more detail in the Subbasin Assessment for the SR-HC TMDL and in Section 3.2.) High suspended sediment concentrations have been observed in many of the agricultural drains and several tributaries where they enter the Snake River (US EPA, 1974 and 1975; personal observations, Upstream Snake River segment (RM 409 to 335), July 1999, July and August 2000, June 2001). A substantial increase in turbidity is visually obvious as an observer moves downstream from the Marsing Bridge to the Weiser Bridge during spring and summer months. This visual trend is supported by data available for the Upstream Snake River segment (RM 409 to 335).

3.5.2.1 ENDANGERED AND THREATENED SPECIES.

The SR-HC TMDL reach provides habitat for the Idaho spring snail (*Pyrgulopsis idahoensis*, formerly *Fontelicella idahoensis* (Frest and Johannes, 2001)). The identified distribution in the mainstem Snake River is from RM 422 to 393 and from RM 372 to 40 (IPCo, 2001a). This snail species is listed as threatened under the Federal Endangered Species Act (ESA), and requires cold, clear, well-oxygenated water for full support.

3.5.3 Sources

Both natural and anthropogenic sources of sediment are known to occur in the SR-HC TMDL drainage. Sources of sediment loading to this reach include natural loading and anthropogenic loading from both point and nonpoint sources. A brief overview of sediment sources is available below. A more detailed description is available in the Subbasin Assessment for the SR-HC TMDL (Section 2.2.4.5).

3.5.3.1 NATURAL SOURCES.

Natural sources of sediment include erosion of rock and soils through wind, precipitation, temperature extremes and other weathering events. Erosion from surface water flow is substantial under average conditions, and erosion from high flow events such as flash floods and snowmelt events can result in greater sediment transport and deposition in a single large event than occurs all year from average flows. Additionally, landslides and debris flows can contribute sediment to surface water systems.

The Bonneville Flood, a catastrophic flood event that occurred approximately 14,500 years ago as the result of the failure of one of the natural dams at Red Rock Pass of Pleistocene Lake Bonneville, deposited fine-grained silty soils over much of the region. The results of this event and the associated erosive processes are visible today in the large bar complexes, fine-grained, easily re-suspended slack water deposits, scoured and eroded basalt and scabland topography in the SR-HC TMDL reach (Link *et al.*, 1999).

As there are no undeveloped watersheds in the SR-HC TMDL reach to use as a reference system for determining natural loading, a rough estimate was derived using the data available for spring runoff in the SR-HC TMDL reach. It was assumed that the majority of the natural sediment loading is delivered during spring runoff-induced flows primarily within the tributary systems. The hydrographs for all major tributaries to the SR-HC TMDL reach were evaluated, peak monthly average flows were identified and available water column concentrations used to calculate total load during spring runoff. Nearly all tributaries to the Snake had the highest flows in April. The exceptions were the Payette River, which had a broader peak of high flows (April and May loading) and the Weiser, which had the highest flow in February. The average relative loading delivered during the high flow month was 23 percent (range = 15% to 36%). This figure was applied as an estimate of natural loading to the mainstem Snake River in the SR-HC TMDL reach.

A necessary set of data for the tributary streams is not currently available. Therefore, natural background concentrations for all tributaries will be determined as part of upcoming TMDL development on the Weiser, Owyhee, and Malheur Rivers, and tributary implementation plans for the Payette and Boise Rivers.

3.5.3.2 ANTHROPOGENIC SOURCES.

All permitted point sources discharging to the mainstem Snake River within the SR-HC TMDL reach (Section 3.0) include maximum total suspended solids discharge limits in their NPDES permits. Most measured total suspended solids concentrations from these point sources are well below the maximum allowable concentrations identified by their NPDES permits. These permit requirements meet or exceed the SR-HC TMDL targets.

Anthropogenic nonpoint sources of sediment in the SR-HC area include agricultural sources such as plowing and flood and furrow irrigation; forestry sources such as logging and streambank disturbance; and urban/suburban sources including construction, stormwater runoff and irrigation.

3.5.4 Transport and Delivery

The primary mechanism of sediment transport in the SR-HC TMDL reach is surface water flow. High flows can transport large amounts of sediment in a wide range of particle sizes and weights. Lower flows preferentially transport lighter, smaller particle fractions. Sediment particles are deposited in areas of streams and rivers where flows decrease and sediments fall out proportionately with size and weight distributions. Sediments deposited in this manner accumulate in areas of the channel where flows are reduced. They can be re-suspended due to increasing flow and carried further downstream. This deposition and transport pattern is evident in the evaluation of suspended sediment data from 1995, an average flow year following a series of lower flow years (Appendix E). In the months of May and June, spring flows transported nearly 200 million kilograms of sediment in the Upstream Snake River segment (RM 409 to 335); the result of several years of in-channel deposition. This mass of transport was nearly three times as large as any other monthly loading that year. Sparse vegetation and timing of snowmelt in areas of the SR-HC TMDL reach and many of the tributary drainages produce conditions favoring high surface runoff and sediment transport.

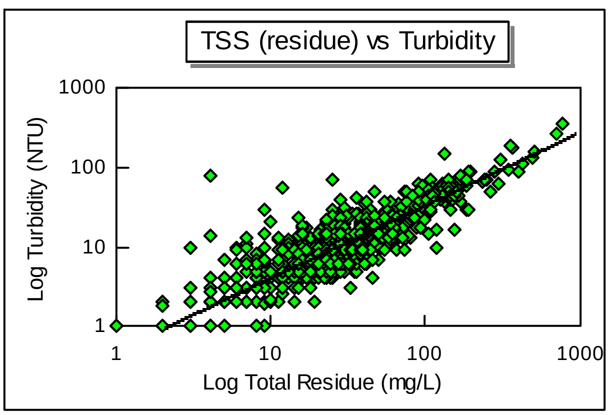
Additionally, land use patterns may influence sediment transport and delivery within the watershed. Flood and furrow irrigation ditches, if they are aligned and sloped toward streams and rivers, act to direct snowmelt runoff to surface water systems. In contrast, sediment basins and settling ponds or other treatment mechanisms on agricultural lands can help to contain snowmelt and stormwater runoff and reduce or remove suspended sediments from both agricultural flows and precipitation events. Similarly, a high density of impervious surface (commonly associated with urban development) increases the volume of runoff from storm events. If properly managed, this stormwater can be diverted to catchbasins or other mechanisms where velocity is decreased and entrained materials are allowed to settle out before water enters surface or ground water systems. Unfortunately, the relative impact of land use practices is not quantifiable with the available data for the SR-HC system.

3.5.5 Data Available for the Snake River - Hells Canyon TMDL Reach

As discussed in the general loading assessment, a fairly robust data set for sediment was available to the SR-HC TMDL effort. Sediment data has been collected over the time period from 1975 to current for both the mainstem Snake River and tributary sites. Data has been collected in the form of suspended sediment concentration (SSC) measurements (n = 344), total residue measurements (equivalent to total suspended solids measurement)(n = 1,754) and turbidity measured by a Hach turbidimeter (n = 1,099). The most robust data set available was the total residue measurement data. As the total residue and total suspended solids methods are considered essentially equivalent, this data will be referred to as total suspended solids (TSS) throughout the remainder of this document. To preserve consistency in the analysis, this data set was compared with the other available data sets in an effort to determine if it was representative of the other data collected and could therefore stand alone. The largest possible number of paired data sets available for each method were compared, and the total suspended solids measurements were found to be well correlated with the turbidity measurements and moderately correlated with the suspended sediment concentration values. The lower level of correlation with the suspended sediment concentration data is not unexpected as the suspended sediment concentration data represented a much smaller and somewhat spatially limited data set (there were much fewer correlated pairs); and studies on a variety of other systems have shown that suspended sediment concentrations often are not well correlated with total suspended solids measurements (Gray *et al.*, 2000; WDOE, 1997). Table 3.5.1 and Figure 3.5.1 show the correlation observed between total suspended solids measurements and the other data sets available.

Table 3.5.1. Comparison of total suspended solids (total residue analysis) data to other sediment data available for the Snake River - Hells Canyon TMDL reach.

Method compared	Correlation coefficient (R^2)	Y-Intercept	Number of data pairs
Turbidity (Hach)	0.825	5.4	705
SSC	0.671	8.3	14



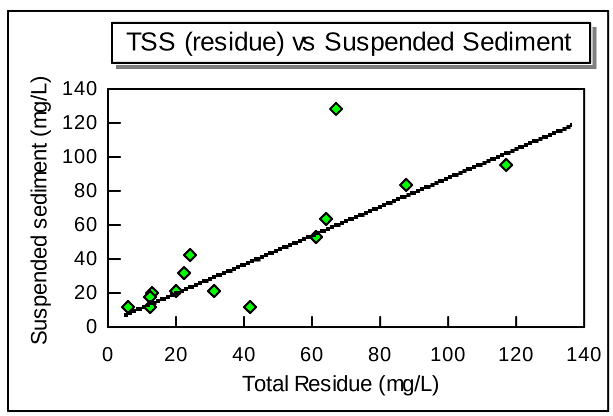


Figure 3.5.1. Linear correlation plots of total suspended solids (TSS (residue)) vs. turbidity measurements and TSS (residue) vs. suspended sediment concentrations (SSC) in the Snake River - Hells Canyon TMDL data set.

There has been a substantial amount of discussion within this TMDL process regarding the appropriateness and inherent biases of total suspended solids and suspended sediment concentration data. Both methods measure organic and inorganic sediment fractions. The analytical method used to determine total suspended solids involves filtration of an aliquot of a water sample that has been swirled to re-suspend sediment particles that may have settled to the bottom of the container. Because the entire sample is not filtered, total suspended solids data carries a slight bias toward the lighter sediment particles. The total suspended solids measurement is therefore somewhat more conservative in estimating algae, silt and clay particles, but would underestimate sand and larger, denser particles to a degree. The analytical method used to determine suspended sediment concentration filters the entire water sample and is therefore not biased toward a particular weight or density class.

While the analytical methods used are similar for both methods, the procedures used to obtain sample aliquots differ and can produce results that differ considerably when larger particle sizes (sand) represents a substantial portion of the suspended material. When fine or very fine particles make up a substantial portion of the suspended material, a higher correlation can be achieved between the two methods (WDOE, 1997).

In the SR-HC TMDL reach, the organic, clay and silt fractions of the suspended sediment are commonly observed to carry the majority of the adsorbed pollutants of concern. In addition, the effect of the organic sediments on dissolved oxygen concentrations within the water column is of concern. As total suspended solids data offers a reasonable correlation with other data sets, and represents a conservative mechanism to assess the sediment load of greatest concern, total suspended solids data were selected as the measure for sediment within this system. In addition, total suspended solids values were found to correlate well with turbidity measurements taken at the same time and place (R2 = 0.825, n = 705). This indicates that total suspended solids measurements will allow a fairly straightforward correlation of TMDL targets and point, nonpoint and direct water column measurement techniques.

Adequate data were available to calculate loading for the SR-HC TMDL reach and inflowing tributaries. Data were also available to calculate point source loading to the SR-HC TMDL reach. Flow and concentration data, average and maximum allowable, were used to determine point source loads. Nonpoint source loading data were not available to this effort.

Duration data to determine direct sediment impacts on aquatic life were not available to this effort. Distribution of the total suspended solids data utilized is shown in Table 3.5.2. A total data set is available in the Appendix E.

It should be noted that often the terms total suspended solids (TSS) and suspended sediment concentration (SSC) are used interchangeably in the literature (usually under the acronym TSS) to indicate the measurement of solids suspended in a water matrix (Gray *et al.*, 2000). This has been the case in the literature review of sediment studies for this TMDL effort. Every attempt has been made to determine the specific analytical method utilized by each study and the acronyms applied in this document are, to the extent possible, consistent with those identified previously.

3.5.6 Determination of Sediment Loading

The available data show that sediment loading to the SR-HC TMDL reach originates almost exclusively from the Upstream Snake River segment (RM 409 to 335). Point source loading represents less than 1 percent of the total sediment loading to the SR-HC TMDL reach. Measured tributary loading to this segment accounts for the majority of the sediment loading to the entire SR-HC TMDL reach, 76 percent, with ungaged (estimated) drain flows accounting for 10 percent of the total system load and unmeasured sources accounting for approximately 12 percent of the total. Sources of this unmeasured load include nonpoint source runoff from both

Table 3.5.2. Distribution of sediment data available for the Snake River - Hells Canyon TMDL reach (1970 through 1997).

Sample Site	Number of Samples	Mean TSS concentration (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Snake River at Marsing	44	21.2	42	2
Tributary Mouths				
Owyhee	169	65.2	562	7
Boise	144	41.1	295	1
Malheur	93	109.2	787	2
Payette	98	36.5	406	3
Weiser	59	27.5	117	2
Drains	194	151.4	1,320	2
Upstream Snake River Mainstem	304	38.3	685	1
Brownlee Reservoir	147	21.1	411	1
Oxbow Reservoir	113	7.8	215	1
Hells Canyon Reservoir	58	9.4	116	1
Downstream Snake River Segment	69	6.9	24	1

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d, 2000a, 2000c, 2000d and USGS, 1999.

anthropogenic sources and precipitation events, unidentified small tributaries and drains, error in gauged flow measurements and in-channel erosion sources.

Sediment loading to the SR-HC system shows a marked increase starting in the month of March and continuing through July and August. The months of April, May and June show the highest overall sediment loading to the system (Figure 2-29 in Appendix G), averaging over 1.5 million kg/day. July through October flow volumes and associated sediment loads are much reduced from the peaks in the previous months. These loads are smaller and relatively steady, averaging about 500,000 kg/day. Because of their direct association to irrigation and summer stormwater runoff activities, these loads are expected to carry the highest fraction of adsorbed nutrient and pesticide loading. Winter loads (November through January) average approximately 300,000 kg/day. Total suspended solids data collected by Boise City Public Works during the year 2000 show a similar trend in temporal distribution (BCPW, 2001). The relative percent sediment loading contribution for each of the SR-HC segments and inflowing tributaries for an average water year is shown in Tables 3.5.3 a and b.

Sediment loads from agricultural drains discharging to the SR-HC TMDL reach were determined using available concentration data and flow data where available. Flow data were not plentiful however, and most flows were estimated using general descriptions and the calculated return flow information by area supplied by the USBR (USBR, 2001). Concentrations were calculated averages where data were not available. These values should be viewed as best estimates. If drain specific data become available during the implementation of this TMDL it should be used

Table 3.5.3 a. Sediment (total suspended solids) loads calculated for point sources discharging directly to the Snake River - Hells Canyon TMDL reach (based on concentration data from 1995, 2000 and design flows).

Point Source	NPDES Permit Number	Location (RM)	Current Design-flow Load (kg/day)
City of Nyssa	101943 OR0022411	385	32 kg/day
Amalgamated Sugar	101174 OR2002526	385	Negligible
City of Fruitland	ID0020907	373	62 kg/day
Heinz Frozen Foods	63810 OR0002402	370	396 kg/day
City of Ontario	63631 OR0020621	369	209 kg/day
City of Weiser (WWTP)	ID0020290	352	213 kg/day
City of Weiser (WTP)	ID0001155	352	Negligible
Brownlee Dam (IPCo)	ID0020907	285	Negligible
Oxbow Dam (IPCo)	101275 OR0027286	272.5	Negligible
Hells Canyon Dam (IPCo)	101287 OR0027278	247	Negligible

in place of these estimates. Land area associated with the drains was calculated at 249,100 acres total (USBR, 2001).

Point source loads were calculated using total suspended solids values specified in NPDES permits specific to permitted facilities and the reported values supplied to the State of Oregon (permitted discharges in Oregon) and the US EPA (permitted discharges in Idaho). Constant concentrations from preceding months were assumed for months where discharge concentrations were not reported. For facilities discharging part time, only that time when discharge occurred was assessed. The total loading value for point sources in Tables 3.5.3 a and b reflects both part time discharges and seasonal discharge requirements for some facilities.

3.5.7 Total Suspended Solids - Relative Organic Content Determination

The relative distribution of inorganic and organic constituents within the total suspended solids measurement is helpful in determining source and treatment alternatives as well as in correlating this effort with that of total phosphorus reduction in Section 3.2. One method of identifying a good portion of the organic material in a sediment sample is to determine the volatile suspended solids (VSS) component. This analytical procedure uses high temperatures to “burn off” the organic content in a total suspended solids sample. The sample is weighed before and after the

Table 3.5.3 b. Sediment (total suspended solids) loads calculated for nonpoint sources discharging to the Snake River - Hells Canyon TMDL reach (based on concentration data from 1995 to 2000 and average flows).

Nonpoint Source	Location	Load (kg/day)
Snake River Inflow	RM 409: Upstream Snake River Segment	677,785
Owyhee River	RM 396.7: Upstream Snake River Segment	66,152
Boise River	RM 396.4: Upstream Snake River Segment	130,466
Malheur River	RM 368.5: Upstream Snake River Segment	92,870
Payette River	RM 365.6: Upstream Snake River Segment	137,887
Weiser River	RM 351.6: Upstream Snake River Segment	53,617
Drains	Upstream Snake River segment (RM 409 to 335)	143,430
Ungaged flows	Upstream Snake River segment (RM 409 to 335)	181,484
Agriculture, Stormwater and Forestry	Upstream Snake River segment (RM 409 to 335)	Included in the ungaged flow loading
Upstream Snake River Segment Total Loading	RM 409 to 335	1,483,691
Burnt River	RM 296: Brownlee Reservoir Segment	13,274
Powder River	RM 327.5: Brownlee Reservoir Segment	14,857
Agriculture, Stormwater and Forestry	Brownlee Reservoir segment (RM 335 to 285)	Cannot be calculated, assumed small
Agriculture, Stormwater and Forestry	Oxbow Reservoir segment (RM 285 to 272.5)	Cannot be calculated, assumed small

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d, 2000a, 2000c, 2000d and USGS, 1999.

procedure and the volatile fraction is determined by difference. A limited data set was obtained from IPCo and Boise City Public Works (BCPW, 2001) monitoring efforts. This information included both the mainstem Snake River and some tributary sites. Total suspended solids and volatile suspended solids data collected from the Snake River are shown in Table 3.5.4 a. This data is plotted in Figure 3.5.2.

The plotted data show that the relative percent of total suspended solids that is volatile (organic) fluctuates over time from ~5 percent to ~ 35 percent. The extremes occur during the months of the year when algae growth would be expected to be at its lowest levels. During the spring and summer months (May through August), a gradual increase in the organic fraction is observed which correlates well with the algae growth observed within the SR-HC TMDL reach. The plot also shows that while there is a substantial change in overall concentration, there is much less fluctuation in the relative amount of organic material associated with the sediment measurements. Throughout the growing season, organic matter represents approximately 15 to 25 percent (~20% average) of the total sediment load within the mainstem Snake River in the vicinity of the SR-HC TMDL reach (RM 441.9 to 340).

Table 3.5.4 a. Monthly mean total suspended solids (TSS) and volatile suspended solids (VSS) data from the mainstem Snake River.

Month	Avg. TSS	Avg. VSS	% VSS
January	6.20	1.80	29.03
February	27.70	2.08	7.49
March	58.40	7.70	13.18
April	31.48	6.68	21.21
May	35.47	5.87	16.54
June	41.07	8.50	20.70
July	33.88	7.82	23.07
August	27.64	7.21	26.10
September	20.87	4.63	22.20
October	13.35	3.43	25.72
November	9.95	3.28	32.91
December	8.02	1.92	23.94

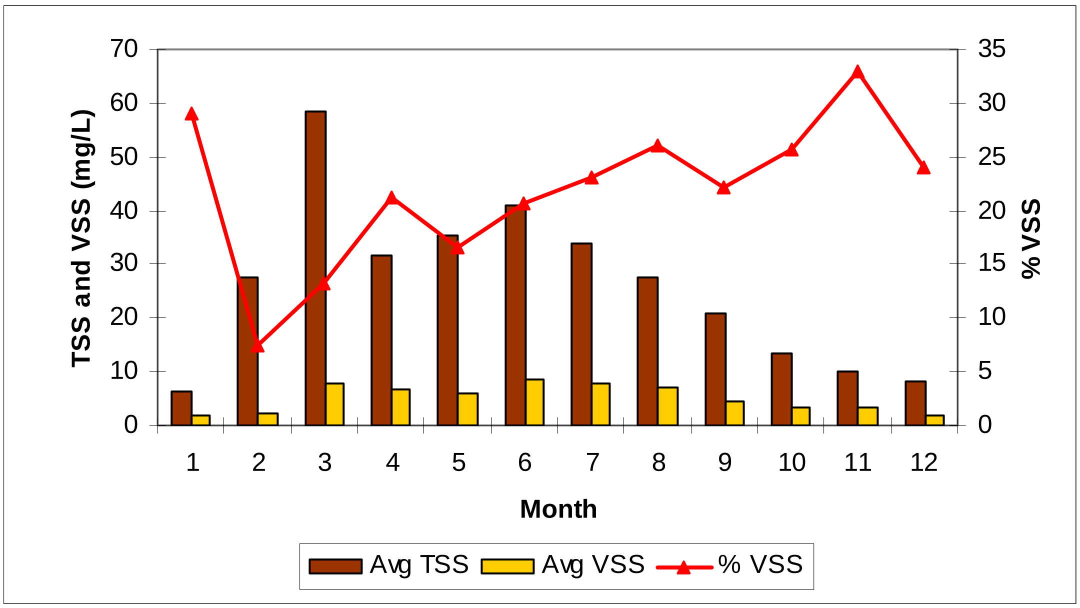


Figure 3.5.2. Total suspended solids (TSS) and volatile suspended solids (VSS) data plotted as monthly means for the mainstem Snake River.

A small data set was also available from IPCo and Boise City Public Works (BCPW, 2001) that allowed a comparison of relative percent organic content between the Snake River mainstem and some inflowing tributaries. This data is shown in Table 3.5.4 b; data is plotted in Figure 3.5.3. The plotted data show that the relative percent volatile suspended solids is reasonably stable within the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach and the inflowing tributaries (Boise and Payette Rivers). The relative percent volatile suspended solids is ~20 percent. This value increases steeply within the reservoir as larger, mostly inorganic sediments drop out and smaller, suspended matter dominates. Again, while the overall concentration of total suspended solids and volatile suspended solids fluctuate fairly widely, the

Table 3.5.4 b. Comparison data for mean total suspended solids (TSS) and volatile suspended solids (VSS) data from the mainstem Snake River, the Lower Boise River and the Lower Payette River.

Location	Mean TSS	Mean VSS	% VSS
Payette River	19.08	2.63	13.81
Boise River	26.65	3.99	14.97
284.4	3.31	1.07	32.40
340	25.29	4.60	18.19
351	42.93	8.87	20.67
403	22.16	4.78	21.59
441.9	16.10	4.89	30.35

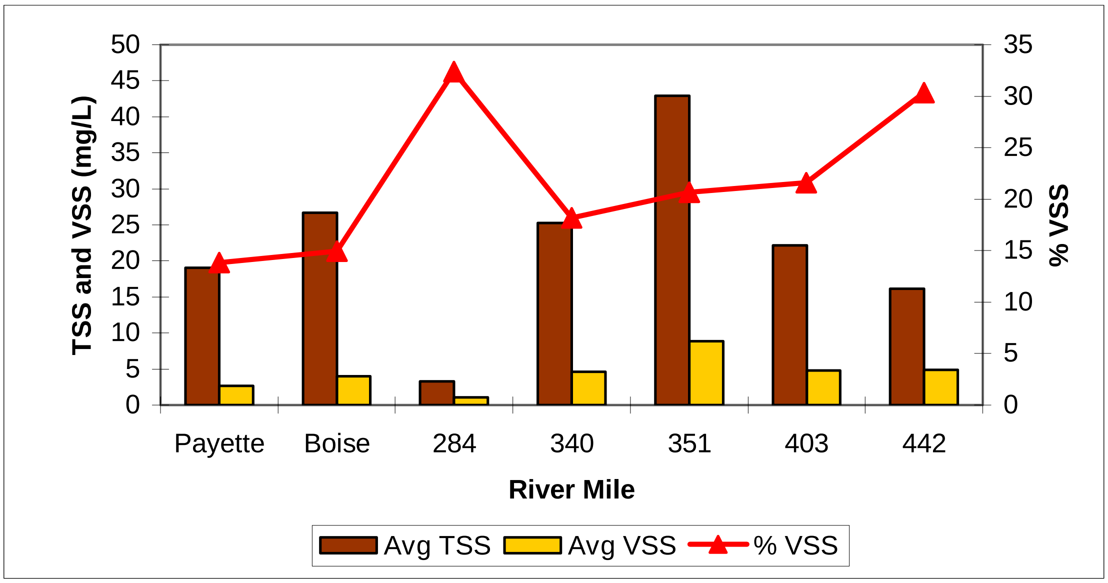


Figure 3.5.3. Total suspended solids (TSS) and volatile suspended solids (VSS) data plotted for the mainstem Snake River and some tributary inflows.

general correlation of total suspended solids and volatile suspended solids remains reasonably constant.

This reasonably stable ratio over the summer growing season indicates that reductions in algae growth within the Snake River will result in a consistent reduction of sediment concentrations in the SR-HC TMDL reach. It also indicates however, that the majority of sediment in the SR-HC TMDL reached, based on these data, is inorganic. Therefore, sediment reductions, while they will be assisted by the measures implemented to attain nutrient reductions, will still need to be addressed separately to attain the identified targets in some places and at some times.

3.5.8 TMDL Determination

Given the water quality concerns associated with sediment in the SR-HC TMDL reach, available information (both site-specific and literature values) was considered in the determination of an appropriate sediment target and TMDL for the SR-HC TMDL reach. Specific to direct negative effects on aquatic life, current targets recognized in other sediment TMDL efforts are reasonably correlated.

Recommendations of less than or equal to 80 mg/L total suspended solids concentration as a daily maximum, and less than or equal to 52 mg/L total suspended solids concentration as a monthly average have been proposed in the upstream Snake River (IDEQ 2000d). Concentrations of less than or equal to 80 mg/L suspended sediment concentration for acute events lasting less than 14 days, and less than or equal to 50 mg/L suspended sediment concentration for acute events lasting less than 60 days have been identified for the Lower Boise River (IDEQ, 1998a). Targets of less than or equal to 56 mg/L suspended sediment concentration have been identified in the Yakima TMDL for both sediment and DDT concerns (WDOE, 1997).

In addition to the protection of designated beneficial uses, the transport of adsorbed nutrients, mercury and organochlorine pesticides through sediment transport and delivery within the SR-HC TMDL reach is of concern. These compounds adsorb to entrained organic matter and fine particles with high surface areas. It is estimated that over 90 percent of adsorbed pollutant loading is carried by the silt/clay and fine to very fine particle fractions of sediment. The majority of the remaining adsorbed load is carried by entrained organic material (Baird, 1995; Clark and Maret, 1998; Rinella *et al.*, 1994).

Sediments in the bed of the Snake River in the Upstream Snake River segment (RM 409 to 335) average approximately 1 percent total organic carbon, 12 percent silt and clay, and 38 percent fine or very fine particles. Sediments in the Brownlee Reservoir segment (RM 335 to 285) average approximately 1.3 percent total organic carbon, 83 percent silt and clay, and 12 percent fine or very fine particles (IPCo, 2000d; Clark and Maret, 1998). As smaller particle sizes tend to travel farther before settling out, the majority of these sediment fractions in the reservoir most likely originated in the Upstream Snake River segment. A reduction in sediment in the SR-HC TMDL reach, and specifically these fractions, will result in a corresponding reduction in pollutant loading for nutrients, mercury and pesticides.

To specifically target that fraction of the entrained sediment that carries the largest pollutant load, total suspended solids-based targets were selected. To target that fraction of annual runoff most likely to contain the adsorbed pollutant load, the temporal distribution of sediment delivery to the SR-HC system was evaluated.

It was observed that the majority of total suspended solids loading to the SR-HC TMDL reach occurred over the summer growing season (April to October). Roughly 70 percent of the total sediment load is delivered during this time period (Table 3.5.5) even though the highest flows in the SR-HC TMDL reach generally occur during the spring season (February, March and April).

Figure 3.5.4, plots A through J (multiple pages) shows total suspended solids concentrations measured at points within the SR-HC TMDL reach and at the mouths of inflowing tributaries. The data sets displayed do not contain equal numbers of data points for the 1975 to 1980 and 1990 to 2000 time periods. In most cases, more data was available in the 1990 to 2000 time

Table 3.5.5. Mean and range of % total suspended solids (TSS) delivered seasonally to the Snake River - Hells Canyon TMDL reach. (Summer is defined as late April through October, spring is defined as February through early April, and winter is defined as November through January.)

	Summer Season	Spring Season	Winter Season
Average Water Year			
Mean % of TSS delivered	72%	19%	8%
Range of %TSS delivered	64% to 86%	27% to 22%	14% to 5%
High Water Year			
Mean % of TSS delivered	69%	29%	12%
Range of %TSS delivered	60% to 85%	20% to 30%	8% to 16%
Low Water Year			
Mean % of TSS delivered	73%	14%	16%
Range of %TSS delivered	55% to 87%	12% to 17%	11% to 28%

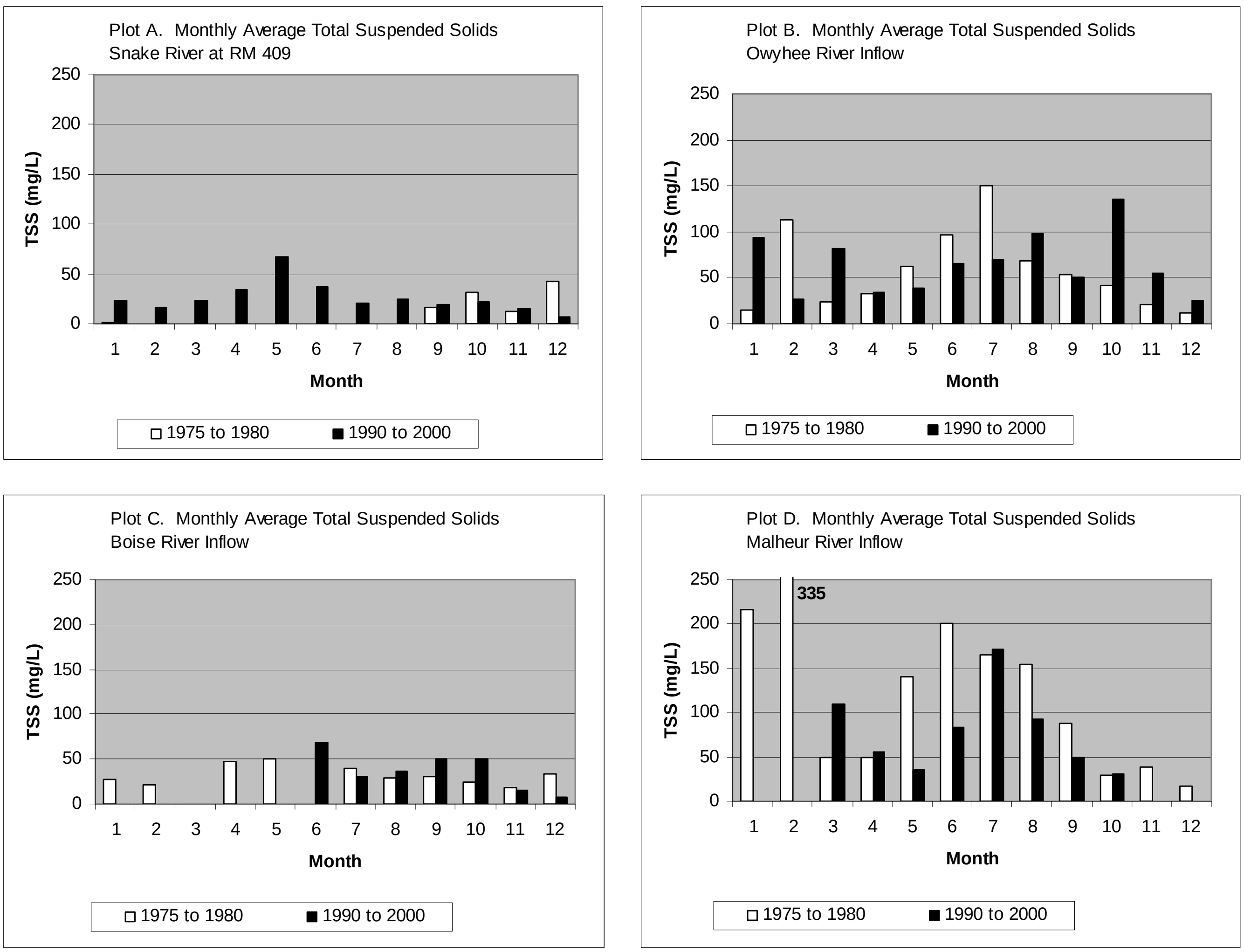


Figure 3.5.4. Mean monthly total suspended solids (TSS) concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

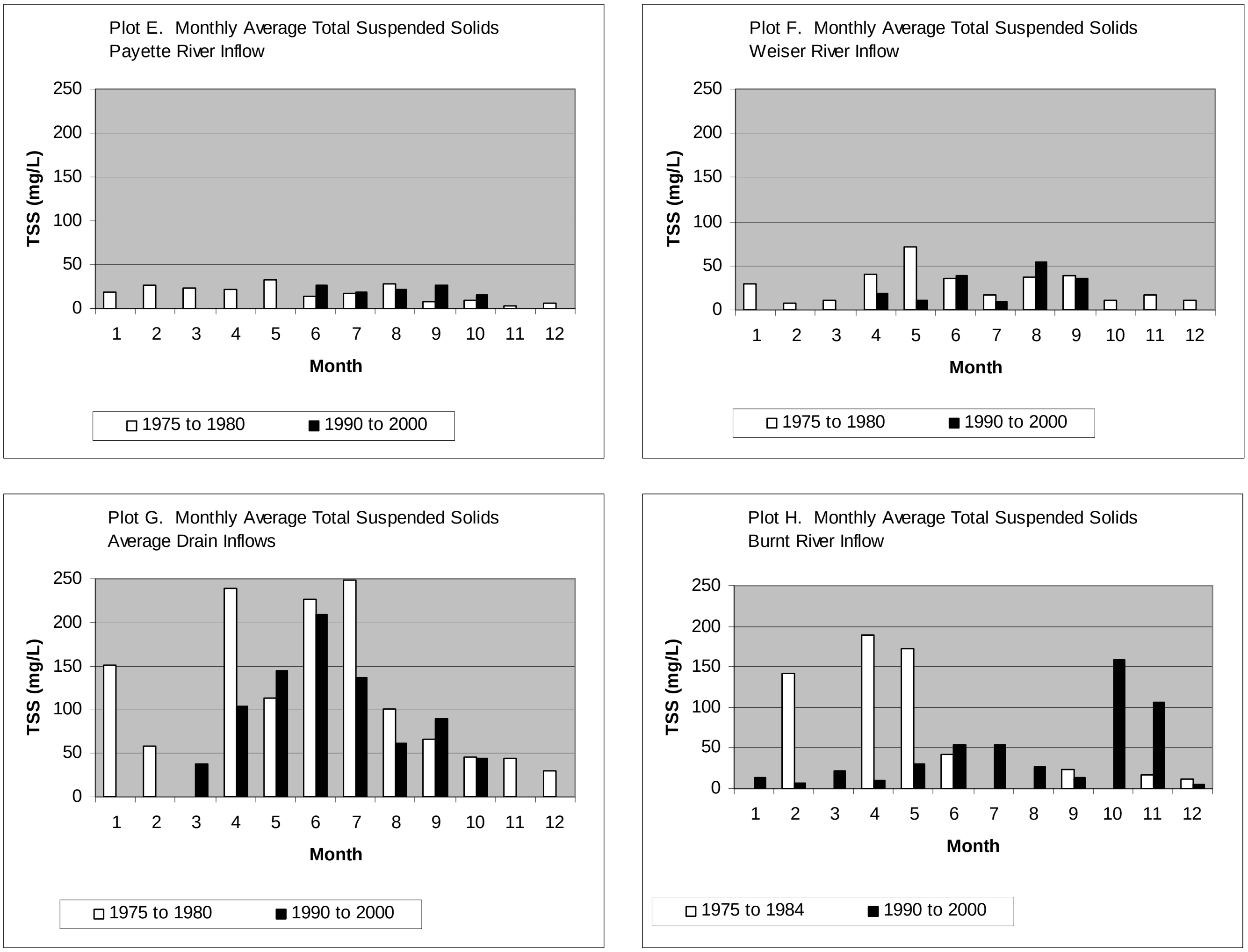
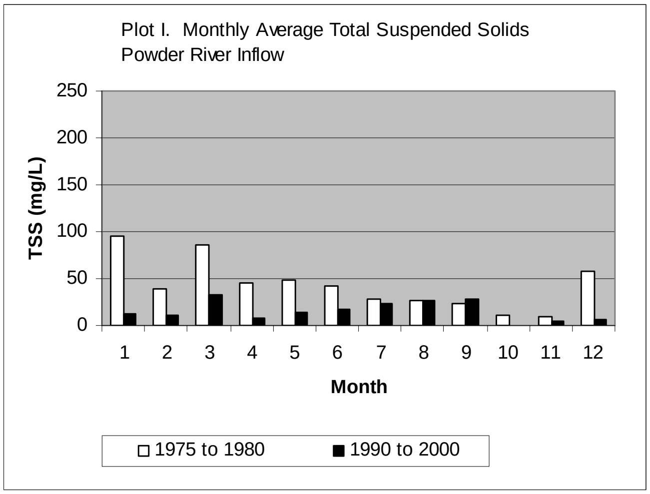


Figure 3.5.4. (cont.) Mean monthly total suspended solids (TSS) concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

period than in the 1975 to 1980 time period. Data is presented as available. Lack of data or smaller than average data sets occurred in some years and locations. Therefore, these limited data may not be representative of average conditions. Scales on all plots were normalized to allow for an easier comparison of relative concentration differences.

The Malheur River (plot D), the Burnt River (plot H) and the Powder River (plot I) show reductions in total suspended solids concentrations from the 1975 to 1980 data as compared to the 1990 to 2000 data.

Total suspended solids concentrations at the mouth of inflowing tributaries do not exceed the average monthly target value of 50 mg/L until late April when they increase sharply. Concentrations continue to increase through July and then decline, dropping below the 50 mg/L monthly average in September. The months in which sediment reduction measures would be the most effective (based on this data) would therefore be from April through August. Winter total



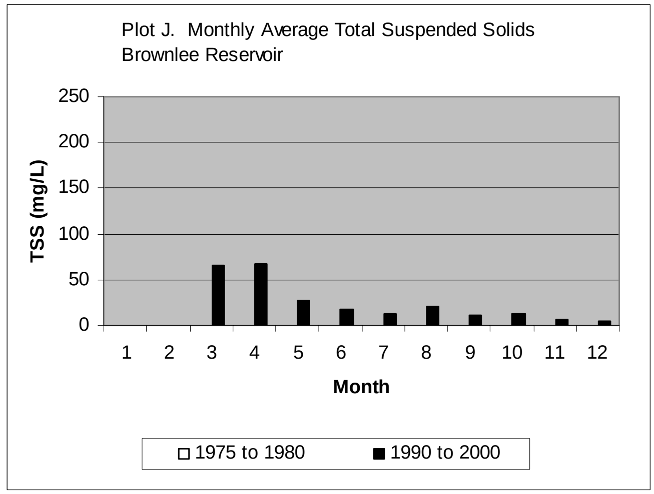


Figure 3.5.4. (cont.) Mean monthly total suspended solids (TSS) concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

suspended solids concentrations in most inflows are rarely observed above 50 mg/L as a daily average and higher, snowmelt induced total suspended solids concentrations do not commonly last more than 14 consecutive days.

Therefore, setting targets that would address the loading occurring this critical time period would encompass the largest portion of the delivered load, while minimizing concerns associated with that time period where natural processes such as snow melt and precipitation result in high flows that are difficult to treat effectively. In the SR-HC TMDL, natural runoff patterns generally show the occurrence of high flow volumes during the months of March and April. Individual tributary systems may experience earlier or later snowmelt and runoff patterns. BMP-based treatment of snowmelt induced spring flows is not always effective. Both stormwater and agricultural BMPs, if properly installed and operated, will function to reduce this runoff-induced loading, but will function less efficiently in times of substantially increased flow volume, especially if it occurs during a time period when vegetation has not re-established after a winter die-off. Therefore, the highest treatment efficiencies will most likely occur during the summer and fall seasons when vegetation is well established and flows are less than spring runoff volumes.

Summer growing season flows are also the most likely sources of legacy pesticide and legacy seed-treatment based mercury transport, as this is when agricultural irrigation use and surface return flows are highest. Soil particles and organic material transported through erosive processes associated with irrigation and stormwater runoff are also likely to contain adsorbed phosphorus. Algae blooms observed in the Upstream Snake River in the late spring and early summer are well correlated with the irrigation season.

In investigating appropriate total suspended solids targets for the SR-HC TMDL reach, several factors were considered, including fish species present, land use distribution (for determining potential for adsorbed pollutant loads), flow and loading distribution, and data available.

At minimum, full support of designated beneficial uses can occur in an environment where sediment and other habitat conditions result in a "none-to-slightly reduced" fishery. An in-depth evaluation of sediment requirements was completed on the Lower Boise River to determine the fishery needs. This work resulted in the identification of a sediment target of less than or equal to 50 mg/L suspended sediment concentration for acute events lasting less than 60 days. This determination was specific to fishery support. In the Mid-Snake TMDL process, a similar evaluation was completed that resulted in the identification of a target of less than or equal to 52 mg/L suspended sediment concentration as a monthly average.

The range of 50 mg/L to 100 mg/L total suspended solids identified by Newcombe and Jensen (1996) was carefully evaluated for application to the SR-HC TMDL reach. The research is specific to rainbow trout, a species known to exist in the SR-HC TMDL reach and while all of the research is not specific to the SR-HC drainage, it represents the current understanding of sediment effects on aquatic life.

Also carefully reviewed was the caution that in order to protect against lethal or paralethal effects on fisheries, sediment concentrations at or above 80 mg/L total suspended solids cannot be sustained for more than 30 days.

The targets evaluated were established based on work that included a broad range of locations and fish species. The fish populations identified within the Mid-Snake and Boise River systems are very similar to those identified within the SR-HC TMDL reach. Therefore, these targets should also be protective of the fish species in the SR-HC TMDL reach.

In light of this information, a two part sediment target for the SR-HC TMDL reach was identified: a conservative target of less than or equal to 80 mg total suspended solids/L for acute events lasting no more than 14 days, and less than or equal to 50 mg total suspended solids/L monthly average. This target will be applied year round. The less than or equal to 50 mg/L total suspended solids monthly average will serve as the load capacity for the SR-HC TMDL. It is the professional opinion of IDEQ and ODEQ that attainment of these targets represent a valid interpretation of narrative standards and will result in support of the designated beneficial uses within the system. This two part target protects the fishery, results in reduction of that specific fraction of the sediment most likely to carry adsorbed pollutants into the SR-HC TMDL reach, and allows an off-ramp for naturally occurring events over which landowners and managers have little control. This target is applied to the SR-HC TMDL reach in the Upstream Snake River, Brownlee Reservoir and Oxbow Reservoir segments (RM 409 to 272.5) as they are listed for sediment in the SR-HC TMDL reach.

The type of sediments identified and the potential for pollutant transport are very similar between the Mid-Snake TMDL reach and the SR-HC TMDL reach. The target selected is conservative in nature (the lower end of the range identified as resulting in no-effect to slightly-reduced fisheries and should therefore ensure minimal negative impacts to the aquatic life in the SR-HC TMDL reach (EIFAC, 1964; NAS/NAE, 1973; IDEQ, 1991; Newcombe and Jensen, 1996, WDOE, 1997).

In absence of duration-specific data that would allow direct interpretation of how sediment transport occurs within the SR-HC TMDL reach; this target was selected as being protective of the system in general. Site-specific data will be collected during the first phase of implementation to refine this target if necessary.

The short term target of less than or equal to 80 mg/L total suspended solids for acute events of less than 14 day duration was derived from the recommendation that sediment concentrations of greater than 80 mg/L total suspended solids for more than 30 days could result in lethal or paralethal effects on fisheries. Given the concern that two, 30 day periods may occur in close proximity and result in a detrimental effect on the fishery, it was decided that a 14 day duration would provide appropriate salmonid rearing/cold water aquatic life support. If two 14-day events were to occur in close proximity (for example one day apart, worst case scenario) the collective effects would still be within the recommended duration for protection of fisheries. Most fish have adapted to survive short duration high intensity events, and most naturally occurring events, while they may result in sustained high flows, do not result in sustained high concentrations of sediment for long duration.

Due to the observed concentration and flow trends within the SR-HC TMDL reach and inflowing tributary systems, the critical period for this target will focus on the summer growing months as that is where the available data show the greatest number of total suspended solids concentrations above 50 mg/L (monthly average) occur. An example of this distribution is seen in the total suspended solids concentrations measured at points within the SR-HC TMDL reach and at the mouths of inflowing tributaries, as shown in Figure 3.5.4

The specific level of reduction realized by attainment of this target is dependent on the type of water year and the hydrology of the surface water system to which it is applied. Setting a concentration-based target means that in high flows, the loading delivered at the target value will be greater than the load delivered at the target value during medium or low flow years.

However, the concentration of total suspended sediment in the water column is a primary factor affecting aquatic life support, so a concentration-based target is reasonable. Additionally, the load delivered during high flow years will still be reduced from the load delivered without TMDL-based reductions. Low and average flow years may show a larger relative percentage reduction in sediment loading by meeting the monthly average 50 mg/L total suspended solids target as loading is based on instream flow (load = flow x concentration). High flow years will also see a reduced sediment load, but the overall relative magnitude of mass realized by the reduction will be smaller because of the higher flows.

Table 3.5.6 shows the calculated loading at current conditions. Calculated loading at the 50 mg/L target level is also shown that incorporates a 10 percent margin of safety. Under these conditions it can be observed that the inflow from the Snake River (at RM 409) and the Boise, Payette and Weiser Rivers does not exceed the target, while the inflow from the Owyhee and Malheur Rivers, and that of the drains exceeds the target and would need to reduce total suspended solids by between 27 percent and 60 percent in order to meet the target criteria at the mouth of the inflow to the Snake River.

3.5.9 Load Allocations

Specific information is presented in Section 4.0. Reductions identified in Table 3.5.6 are specific to the mouth of those tributaries where discharged total suspended solids concentrations are greater than 50 mg/L monthly average. These reductions are expected to minimize site-specific degradation of habitat and impairment of designated uses at the inflow point within the mainstem Snake River.

Table 3.5.6. Current sediment loads, projected loading based on 50 mg/L total suspended solids (TSS), and percent reduction realized (based on concentration data from 1995, 1996 and 2000, and average flow values).

Sample Site	Current Load (TSS) (kg/day)	Projected Loading at 50 mg/L (TSS) (kg/day)	% Reduction
Snake River at Marsing	677,785	1,054,463	
Tributary Mouths			
Owyhee	66,152	48,007	27
Boise	130,466	148,569	
Malheur	92,870	42,062	55
Payette	137,887	296,530	
Weiser	53,617	121,144	
Drains	143,430	57,628	60
Ungaged flows	181,484	118,178	35
Upstream Snake River Mainstem	1,483,691	1,886,581	
Burnt	13,274	9,713	27
Powder	14,857	26,348	
Brownlee Reservoir	193,093	1,888,952	
Oxbow Reservoir	275,470	1,904,434	